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Urban Transit Bus Accessibility Considerations

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cuta actu

Canadian Urban Transit Association
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Urban Transit Bus Accessibility Considerations

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August 1995

CUTA Mission Statement

CUTA is the association of providers of urban transit services, suppliers and related organizations in Canada. Its mission is to promote the role of urban transit in enhancing mobility, and to support its members in the fulfilment of their mandate.

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The contents of this report reflect the views of the author(s) based on their research, but do not necessarily reflect the official views or opinions of the Canadian Urban Transit Association, nor of the organizations funding the Strategic Transit Research Program.

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Abstract

With the introduction of low floor buses and the increasing cost and demand of paratransit, there has been a renewed interest in making conventional buses more accessible to pecple with disabilities. Boarding and securement technology are two of the most important considerations in achieving this goal of wider accessibility. However, the impact of these technologies on the regular operation of buses needs also to be examined. For small buses in Canada and all buses in the U.S., standards exist that require securement of passengers with mobility aids. These standards contrast against some studies conducted in Europe which conclude that no securement system is required at all for passengers in wheelchairs on transit buses.

To further understand the complexities involved in providing safe and efficient accessibility, the Canadian Urban Transit Association has conducted a study of **Urban Transit Bus Accessibility Considerations**. This study investigates the two most common boarding and securing technologies currently being used in North America for wheelchair and scooter users, as well as the standards that require them. The "protected position" approach of some European studies is also discussed. The study concludes with some recommendations that transit systems should consider when increased accessibility on standard size buses is desired.

Of four appendices, two feature photographic sequences of a simulated boarding for scooter and wheelchair, the third features the results of a German study on the stability of wheelchairs on buses, and the fourth contains a CUTA Forum article about London Transport's low-floor bus experience.

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Urban Transit; Accessibility; Securement Technology; Low-floor buses	English (Ce rapport sera disponible en français)
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Résumé

Avec l'arrivée des autobus à plancher surbaissé et les demandes et coûts croissants du transport adapté, il s'est développé un nouvel intérêt afin de rendre les autobus urbains plus accessibles aux personnes à mobilité réduite. Les technologies de l'embarquement et des systèmes d'attache constituent deux des principaux aspects de la poursuite de cet objectif d'une accessibilité accrue. L'impact de ces technologies sur l'opération régulière des autobus, toutefois, doit aussi être examiné. Il existe, pour les petits autobus au Canada et tous les autobus aux États-Unis, des normes exigeant que les passagers utilisant des aides à la mobilité s'attachent. Ces normes contrastent avec certaines études qui ont été effectuées en Europe et qui arrivent à la conclusion qu'aucun système d'attache n'est nécessaire pour les passagers en fauteuil roulant dans les autobus urbains.

Pour mieux comprendre les complexités d'une accessibilité sûre et efficace, l'Association canadienne du transport urbain a fait une étude des questions d'accessibilité relatives aux autobus urbains. Cette étude se penche sur les deux technologies d'embarquement et d'ancrage les plus répandues présentement en Amérique du Nord, à l'intention des utilisateurs de fauteuils roulants et de scooters, de même que les normes qui les exigent. L'approche européenne d'une «position protégée» est aussi considérée. L'étude se termine par certaines recommandations dont les réseaux de transport en commun devraient tenir compte lorsqu'elles désirent une meilleure accessibilité des autobus de grandeur normale.

Des quatre annexes, deux présentent des séquences photographiques d'un embarquement simulé d'un scooter et d'un fauteuil roulant; le troisième montre les résultats d'une étude allemande sur la stabilité des fauteuils roulants à bord des autobus et le quatrième renferme un article de CUTA Forum ACTU sur l'expérience de London Transport avec ses autobus à plancher surbaissé.

Mots-clés	Langue
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EXECUTIVE SUMMARY

Accessibility to public transit by mobility impaired passengers has received renewed attention. This increased attention has largely focused on:

- the introduction of low floor buses into the market, thus increasing the possibility of attracting more disabled passengers to the fixed route system, and
- the increased cost and demand for paratransit services.

The Canadian Urban Transit Association (CUTA) has addressed the problem of accessibility to transit buses through a project carried out under CUTA's Strategic Transit Research Program (STRP). Special emphasis has been placed on research efforts concerning wheelchair accommodation and related safety standards for full size transit buses, because this has emerged as a strategic and urgent concern for the urban transit industry. Although the specific emphasis was on securement systems, other important and related issues were analyzed and investigated at the same time, e.g., fare payment, access by ramp or lift, impact on other passengers, drivers responsibilities, companions etc.

Five Canadian transit systems were visited and a number of U.S. transit systems were interviewed. In addition to the site surveys, securements and future securement concepts in North America and abroad were investigated. The results of an American Public Transit Association (APTA) survey were reviewed, as well as securement standards and relevant research on the subject from Germany, the UK, Sweden and France.

The scope of this study includes several aspects facing urban transit systems in regard to accessibility. Only the aspects relating to the operation and technology of securements, boarding and alighting are discussed here. There are of course many other issues that are relevant to accessibility such as financing, marketing, cost, training, monitoring, management etc., but they have not been part of this investigation.

Passenger target group

The target group for this investigation included passengers using different types of wheelchairs or scooters, e.g., manual wheelchairs, sports chairs, electric converted wheelchairs, electric powered chairs and three-wheel scooters. Persons using different wheelchairs have different capabilities and requirements.

Aside from this group there are persons using other mobility aids such as walkers, one or two canes, arm or elbow crutches. They require not so much a large space, but an obstacle free and stable floor surface without steep grades. The elderly require assistance for balancing and stabilizing their standing or sitting posture, e.g. stanchions, armrests on seats, guardrails etc.

Accessible transit buses and systems in Canada

Presently there are several manufacturers in Canada that either produce low floor buses or have buses in the prototype stages. New Flyer of Winnipeg is supplying most of the Canadian low floor buses to date. Ontario Bus Industries in Toronto has built the Orion VI low floor prototype, which is undergoing testing and being prepared for production. Nova Bus in Montreal produces a low floor bus and is planning to provide one location for a wheelchair. Site surveys of transit operations were undertaken in Victoria, Vancouver, Edmonton, Calgary and St. Albert in early 1994. Of the five transit operations investigated, one was using regular lift-equipped buses, manufactured by Motor Coach Industries and New Flyer, the other four used low floor buses manufactured by New Flyer.

Securement types

There are two main securement systems in use in Canadian transit buses, the wheel-rim clamp and the angled stop. Both immobilize the wheelchair with belts and hooks which are attached from the rear to the wheelchair frame. These systems prevent the wheelchair from becoming loose under regular driving conditions, including severe braking and cornering. These securement systems are less complex than those typically used in paratransit vehicles because of much lower acceleration/deceleration forces experienced by larger buses.

Passenger restraint

In addition both systems can also have a passenger lap restraint system, consisting of two parts, a retractable buckle belt and a retractable tongue belt located at each side of the securement just above the floor. These belts must be pulled out of their respective housings and connected in the lap of the passenger. Use of the belt system is not mandatory for persons over 16 years of age.

Other securements

Other securements which are in use in the U.S. were reviewed, including the four-point belt system with a three-point belt passenger restraint, the Independent Locking System (ILS), the Cleveland harness prototype, and the protected position used in England and Germany.

Foreign Research

The issue of safety standards and wheelchair securements in low floor buses is an international issue. Several countries are involved in research efforts to solve this problem.

European Research

Germany was one of the first countries to implement accessible low floor buses, but also conducted two significant studies on wheelchair stability and securement design.

The conclusion of these studies indicates that it is possible to transport wheelchair passengers in a transit bus **safely without a securement system** provided that:

- there is a "confined space" for a wheelchair passenger with a back-support panel
- the wheelchair passenger is facing rearwards with the wheelchair back in contact with the back support
- the brakes of the wheelchair are firmly applied the driver exercises reasonable driving habits
- the speed does not exceed city speed limits

As a result of this research, a number of German transit systems have developed a "protected position" design for accommodating mobility aids on-board full size buses. This design fulfils the above mentioned requirements and is being used in the cities of Essen, Berlin, Bremen, Cologne, and Aachen.

in England, the "protected position "design has been further refined and is being demonstrated since early 1994 in London. In these buses the wheelchair position is located on the door side. Wheelchair users are instructed to board and face rearwards, positioning themselves with a padded rest behind them, a padded area on the window side (with flip down seats), and a vertical stanchion on the aisle side. No other securement devices were felt to be required, nor is a passenger restraint provided.

In Sweden "...starting points for a wheelchair securement for use in public transportation and in special transportation services for wheelchair users are:

- the safety and comfort for the wheelchair occupant should as far as possible be the same as is offered a traveller sitting in an original seat in the vehicle
- the securement must fit common wheelchairs and no parts of it must be fixed to the wheelchair
- the securement system must be easy to handle when securing the passenger and the wheelchair.

The wheelchair securement system must keep the wheelchair safe when it is exposed to horizontal and vertical forces. When exposed to these forces, a wheelchair must not overturn, twist or shift its position. The securement system shall fit ordinary types of wheelchairs."

APTA survey

In 1993, the American Public Transit Association (APTA) conducted a user survey of wheelchair securement systems and received many responses from US and Canadian transit systems. This survey was being conducted to determine current usage and practices regarding wheelchair securement devices. The survey indicated that the systems mostly used were: the wheel-clamp combined with front and rear belts, and the Q-Straint (or variations of Q-Straint). About one third of the drivers had no problems, another third found the belt application "too time consuming", "hard to work", and being "too close to the passenger." Since both these systems are based on belts and hooks, storage and handling of belts seemed to represent another problem. For the general public belts, which do not retract

completely can create a hazard when hanging loose or laying on the floor.

In light of the experience of present operators the following are suggested issues for discussion:

- investigation into passive securement systems,
- use of the front or mid door service entrance,
- location of wheelchair positions,
- review of safety standards for passengers in large transit buses.

Experience with Mobility Aids

The investigation has shown that there are several operations which compose the complete system of accessibility in a bus: boarding, fare payment, proceeding to place, preparation of place, manoeuvring into position, deployment of securement, stop request, and alighting. These operations are either very time consuming (use of lift, manoeuvring into securement position, deployment of belts, detachment of belts), interfering with other passengers (manoeuvring into securement position), or require the assistance of another person (deployment of belts, flipping seats up or down).

Boarding

One major difference between a lift-equipped regular bus and a ramp-equipped low floor bus is the boarding system for wheelchair/scooter passengers, the other is the seating capacity. The following section summarizes the experience with both boarding systems separately and continues with other related issues which do not differ much from each other, regardless of which type of bus is used.

Low floor, ramp-equipped buses make access for all passengers, including those using a wheelchair/scooter, easier. The introduction of these buses has been well received by both the population with mobility impairments and the general public. Although not having to negotiate steps decreases boarding and alighting times only marginally for the general public, it nevertheless reduces the probability of accidents. For passengers using a wheelchair/scooter, a ramp is deployed by the driver and swings out extending onto the sidewalk/platform about 1.02 m (40"). With the bus kneeled and the ramp resting on a curb, the inclination of the ramp is very easy to negotiate. However, the inclination of the ramp when deployed to the road is rather steep (about 13 degrees) and can create a safety problem for scooters and other wheelchairs. The ramp can be operated manually by the driver without interrupting or delaying route service. Drivers prefer the ramp over the lift, because of its simplicity of operation. Another reported advantage of the ramp is that it is also often used by other mobility impaired passengers, e.g., those using walkers, canes and crutches, and the general public. Nevertheless the ramp is not without inconveniences. The driver must alert waiting passengers outside to make room for ramp deployment and the ramp storage area inside the bus must be kept free of dirt and silt, especially in the winter.

Lift-equipped buses present some problems for transit systems in Vancouver, Champaign Urbana and Ann Arbor. At the time of implementation several years ago, they probably represented the best possible concept on the market, but with the introduction of low floor buses and ramps this concept seems to have several

disadvantages. Lifts are technically complex products and mechanical failures cause service route schedules to be interrupted. In the case of lift malfunction a supervisor must be dispatched or the bus be replaced. In either case the result is schedule delays, inconvenience for passengers and increased costs for the transit system. While the lift is in use, no other passenger can board the bus until the full lift cycle is completed, which requires approximately 12 operations. One full boarding cycle can take two to three minutes. Boarding and alighting for elderly passengers via stairs creates longer dwell times and increases the probability for accidents.

Fare payment
The fare payment box is located near the driver's station, and the height to insert coins can vary from 1.02 m - 1.17 m (40" - 46"). For a person in a wheelchair 1.17 m (46") is too high to visually verify correct insertion. For the elderly and disabled the handling of coins can create a problem due to finger agility problems, although most elderly and disabled passengers have a pass. For the passenger in a wheelchair or scooter the fare payment in low floor buses sometimes creates another problem when he/she gets too close to the fare box before realizing that there is not enough room left to turn 90 degrees into the bus. In this case the driver or companion must assist. Scooters with baskets mounted at the front are especially difficult to turn.

Proceeding to the seat
The location for a wheelchair/scooter passenger which is also designated as priority seating is behind the front wheel wells. In high floor buses the wheelchair/scooter passenger must pass vertical stanchions and side-facing seats on each side with passenger's feet extending into the centre aisle. In low floor buses wheelchair/scooter users must pass between front wheel wells. Neither case usually presents a problem, as long as the area is kept clear of standees.

Preparation for securement
In an ideal scenario the wheelchair passenger arrives and all seats are flipped up. The worst scenario is that all seats are down and must be lifted. A lever must be operated to bring the seat from its horizontal to its vertical position. On the transverse seat this means lifting a double seat. Pulling the lever and lifting the seats requires considerable strength, and is especially difficult when working from a seated position in a wheelchair or scooter. Most wheelchair passengers cannot perform this operation. In addition, it requires the wheelchair/ scooter user to first manoeuvre close to all seats in order to flip them into the vertical position, followed by a second manoeuvre to get into the securement position. All this adds time to the boarding cycle and may require asking other passengers to vacate their seats if they occupy priority seats. This is unpleasant for the wheelchair user as well as for other passengers.

Manoeuvring into securement position
Because the wheelchair/scooter passenger gets in facing the rear of the bus, he/she must turn the chair 180 degrees in order to back against the securement and face forward. This turn must take place in the centre aisle as this is the only space in the bus large enough to allow such a manoeuvre. If a wheelchair/scooter

user turns, some of the seated passengers may be asked to vacate their seats to make room for the wheelchair, which creates an unpleasant situation for the seated person and for the wheelchair passenger. Most of the time the turn cannot be made in one movement and requires several back and forward movements, adding time to the operation and stress to the passengers.

Securement and passenger restraint

Wheelchair securements in Canadian urban buses are mainly of two types: the wheel-rim clamp, and the angled stop. Both immobilize the wheelchair with belts and hooks which are attached from rear anchor points to the rear or front of the wheelchair frame. These systems immobilize the wheelchair against forces during regular transit operation, including severe braking and cornering. No accidents have been reported to date, which would tend to indicate that these systems are adequate for this purpose.

The main problem with these systems was found to be in the operation. Both require the help of a companion/assistant to deploy the hooks and belts and apply tension to the belts. The great majority of wheelchair/scooter users cannot reach behind and down to fetch belts and hooks, or connect them to the rear of the wheelchair/scooter or to floor anchors. Even backing into the wheel-clamp with one large rear wheel requires turning the head and upper body, verifying the position and engaging the wheel, which some wheelchair passengers have difficulty doing. The driver often assists, even though it is not his/her responsibility. The principle of the two-for-one fare has therefore been introduced in several transit operations in Canada in order to relieve the driver of this duty. The companion rides free but is responsible for all tasks connected with deploying and detaching belts, and helping the passengers exit the bus.

In some transit systems the front belt used for the scooter is stored in a box over the wheel well and must be requested from the driver, in other operations the belt is attached with one end permanently to the floor and the other end hooked under the seat. Both solutions are not satisfactory. The first requires the driver to be responsible for the return of the belt to the box, the second creates dirty and soiled belts. This problem was also found with securement belts which do not retract fully and hang loose or lay on the floor, thus creating hazards for other passengers.

Stop request

There are several methods used for the wheelchair passenger to request a stop, a vertical pull cord, a sensitive touch strip, or a push button. All are mounted within easy reach for the wheelchair passenger and are part of the same stop request system used by the general public. When activated, an audio signal is heard and a lighted sign at the front of the bus is displayed. All methods were found easy to use. It was nevertheless suggested that the stop request activated by the wheelchair passenger should provide a separate signal to the driver so that he can prepare for the deployment of the lift or ramp.

Alighting
The general public exits through the mid door, the wheelchair/scooter passenger through the front door. In case of a lift, the driver must alert waiting passengers outside that the lift will be deployed, although there is a red flashing light on the outside of the bus near the door as well as an audio signal. The wheelchair passenger must wait until the driver has the platform moved from the stowed into the exiting position, which can only be done after the bus has come to a complete standstill, is kneeled, the front doors are opened and locked, the four flashers are switched on, and the main brake is applied. Only after the lift/platform cycle is complete, can other passengers board. The lift platform does not allow a standing passenger, e.g., one using crutches, canes or a walker to board, since the vertical head clearance between the platform in its elevated position and the door frame is only 1.50 m (59").

In case of the ramp, the driver must alert passengers waiting outside, that he will deploy the ramp. Once deployed, the wheelchair/scooter passenger can exit and all waiting passengers board using the ramp. This is an added convenience and reduces boarding time. The ramp is also convenient in winter when the bus cannot stop close to the curb and there is a larger gap between bus and curb. There is an audio signal activated while the ramp is in use to alert other passengers. It was reported that some passengers using hearing aids experienced interference from the ramp's audio signal frequency.

Safety standards
In Canada there are no regulations or standards for wheelchair securement systems in large buses. CSA Z604 and Z605 are standards for the design of mobility aids and their securement to be used in motor vehicles of less than 6500 kg GVW, but do not specify other aspects of accessibility for transit buses.
In the US, the American with Disabilities Act (ADA) requires buses with GVW over 30,000 lbs. to provide a 4-point wheelchair securement system as well as a passenger's lap and shoulder belt restraint systems to withstand 2000 lbs. per securement leg or a minimum of 4000 lbs. per mobility aid. Vehicles under 30,000 lbs. must restrain forces of up to 2,500 lbs. per leg or a minimum of 5,000 lbs. per mobility aid. This is the equivalent of withstanding a deceleration force of 20 g.

Recommendations
With the rapidly increasing move towards low floor buses in transit systems in Canada, several aspects of accessibility must be solved urgently, otherwise transit systems will be faced with costly retrofitting in the years to come.

All accessibility aspects in a bus are interwoven, e.g., the service door position has a bearing on the location of the wheelchair position; the securement system on the fare policy; the seat capacity on the securement system; etc. None of the aspects can be considered in isolation, but must be viewed in terms of the constraints imposed on other elements.

Based on this investigation the following recommendations are considered important in order to make access to transit buses more efficient for the transit systems and the operators, and more convenient for wheelchair /scooter passengers:

1.Passenger safety
- determine the acceptable levels of safety for all bus passengers, including standees and those using mobility aids, and develop standards
- investigate techniques for reducing or relocating manoeuvring space for wheelchair/scooter passengers without interfering with the main passenger flow within the bus
- explore German and UK experience with protected position designs

2. Technologies
- investigate forward, sideways or angled facing of wheelchair/scooter passengers
- investigate protected position designs for accommodating mobility aids in the Canadian context make securement adaptable to all commonly used wheelchairs and scooters
- investigate use of the centre door for wheelchair/scooter access
- develop differentiating signal for stop request by wheelchair user

3. Operation
- reduce the need for hooks and belts for securement
- reduce driver involvement for securement or physical assistance

4. Policy
- determine the appropriate level of customer service and protection (equal or superior treatment for passengers with disabilities?)
- investigate capacity considerations
- investigate self-service fare payment, eg. honour system, smart card etc.
- investigate two-for-one companion fare policies

1. INTRODUCTION

The Canadian Urban Transit Association (CUTA) is the association of providers of urban transit services, suppliers and related organizations in Canada. CUTA has an active research program, and has conducted, through its Strategic Transit Research Program (STRP) a research effort concerning wheelchair accommodation and accessibility considerations for full size transit buses, because this has emerged as a strategic and urgent concern for the urban transit industry. Although the specific emphasis was on securement systems, other important and related issues were analyzed and investigated at the same time, e.g., fare payment, access by ramp or lift, impact on other passengers, drivers responsibilities, companions etc.

1.1 Objectives

The objective of this study is to provide a document for transit systems and managers in the urban transit industry which analyzes existing securements already being used in Canada and discusses developments in North America and abroad.

1.2 Approach

In addition to the site survey of five major Canadian urban transit operations, a number of other issues were investigated or reviewed. An analysis of existent securements used in operations in Canada was carried out, as well as securements under development and future concepts in North America and abroad. The results of an American Public Transit Association (APTA) survey were reviewed, as well as the CUTA draft document, securement standards and relevant research on the subject from Germany, the UK, Sweden and France.

1.3 Scope

The scope of this study includes several aspects facing urban transit systems in regard to accessibility. Only the aspects relating to the operation and technology of securements, boarding and alighting are discussed here. There are of course many more issues which are relevant to accessibility but they have not been part of this investigation such as financing, marketing, cost, training, monitoring, management, etc.

2. PASSENGER TARGET GROUPS

This chapter discusses the passenger target groups, and identifies 1) general characteristics, 2) wheelchair/scooter types, 3) mobility aid envelopes and 4) passenger requirements.

2.1 General characteristics

The target group for this investigation included passengers using different types of wheelchairs or scooters, e.g., manual wheelchairs, sports chair, electric converted wheelchairs, electric powered chairs and three wheel scooters (Fig. 1 - Fig. 5). Persons using different wheelchairs have different capabilities and requirements. A person with good upper body strength in a sports-chair or a manual chair can usually bend down, attach and detach belts, manoeuvre in a tight space and even jump thresholds of up to 75 mm (3"). In contrast, a person using an electric wheelchair with little upper body, arm and hand strength, requires the help of another person to attach and detach belts or hooks. Scooter users are often persons who have difficulties judging the space requirements of their devices, especially when it comes to turning and positioning.

Aside from this group there are persons using other mobility aids such as walkers, one or two canes, arm or elbow crutches. They require not so much a large space, but a barrier free and stable floor surface without steep grades. Elderly persons require assistance for balancing and stabilizing their standing or sitting posture, e.g., stanchions, armrests on seats, guardrails, etc.

2.2 Wheelchair/scooter types

The types of wheelchairs and scooters commonly used are:
1. Manual standard wheelchair
2. Manual sports chair
3. Electric converted wheelchair
4. Three-wheel scooter
5. Electric powered chair with four small wheels

Fig 1. Manual standard wheelchair
Two large rear wheels, solid or pneumatic tires; foldable; two small solid or pneumatic front casters; some with detachable arm and foot rests.

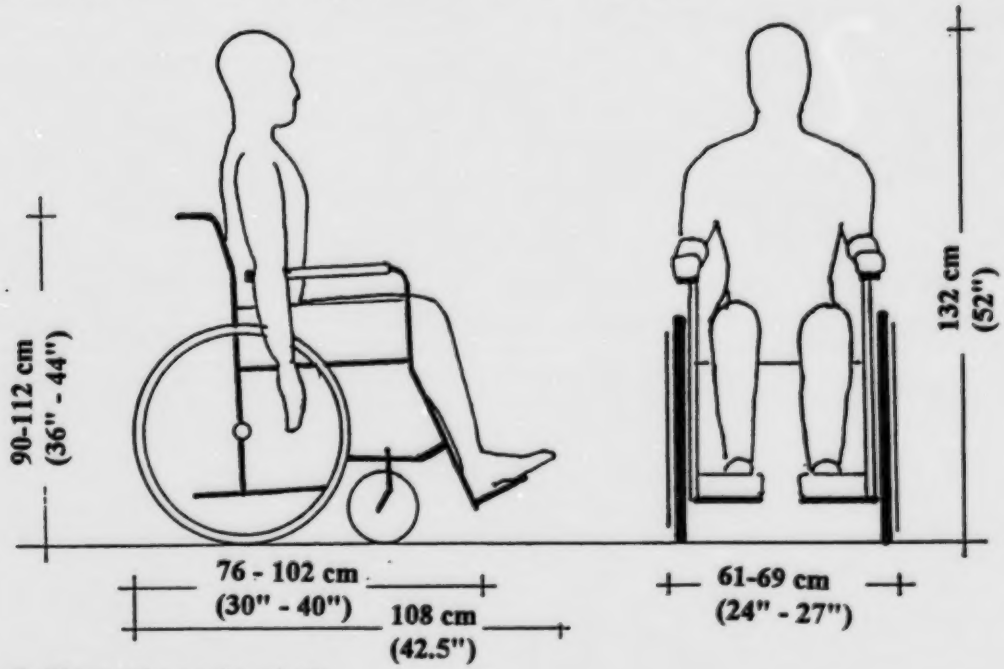


Fig 2. Manual sports chair
Two large rear wheels with camber from 0 - 5 degrees; low back; foldable; small front casters; light weight.

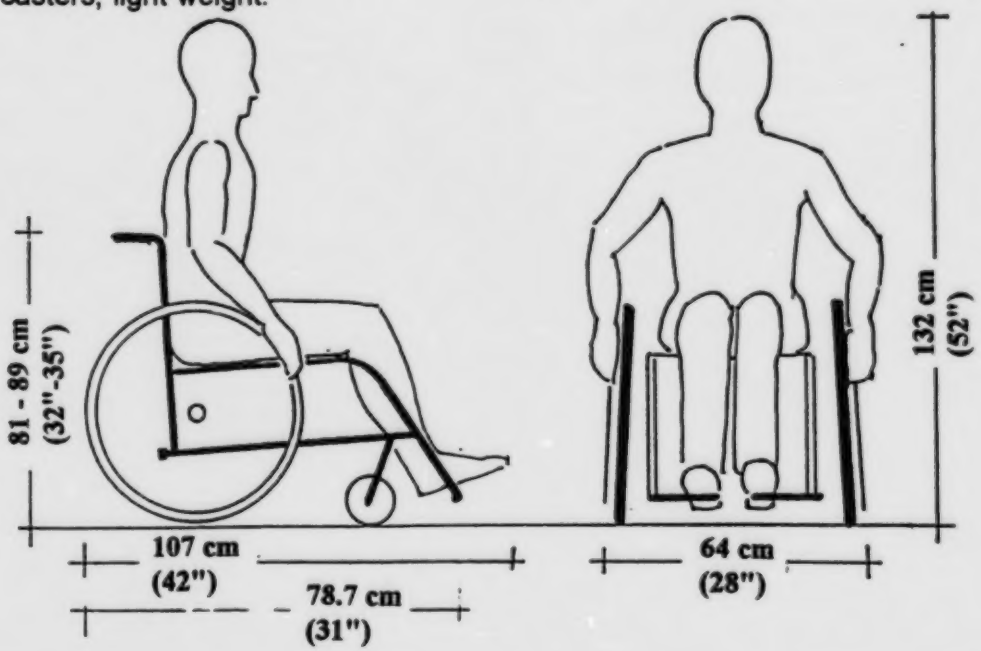


Fig 3. Electric converted wheelchair
Battery powered; two large rear wheels with wide, air-filled tires; two front casters with air-filled tires; joy stick operated.

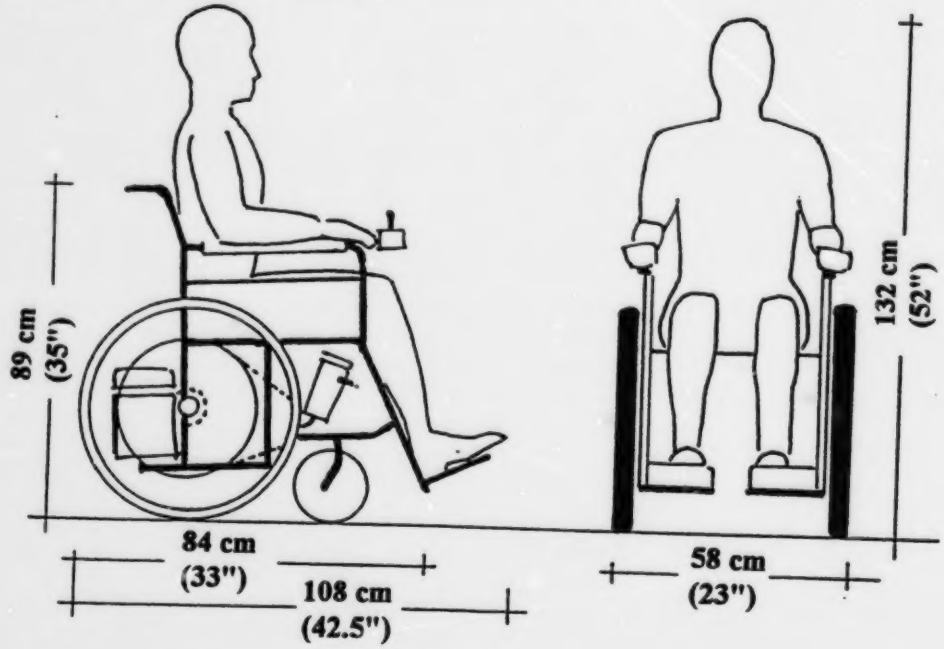


Fig 4. Three-wheel scooter
Battery powered, three small air-filled tires, one front wheel steering, swivel seat; front and rear basket (----) option used by many owners

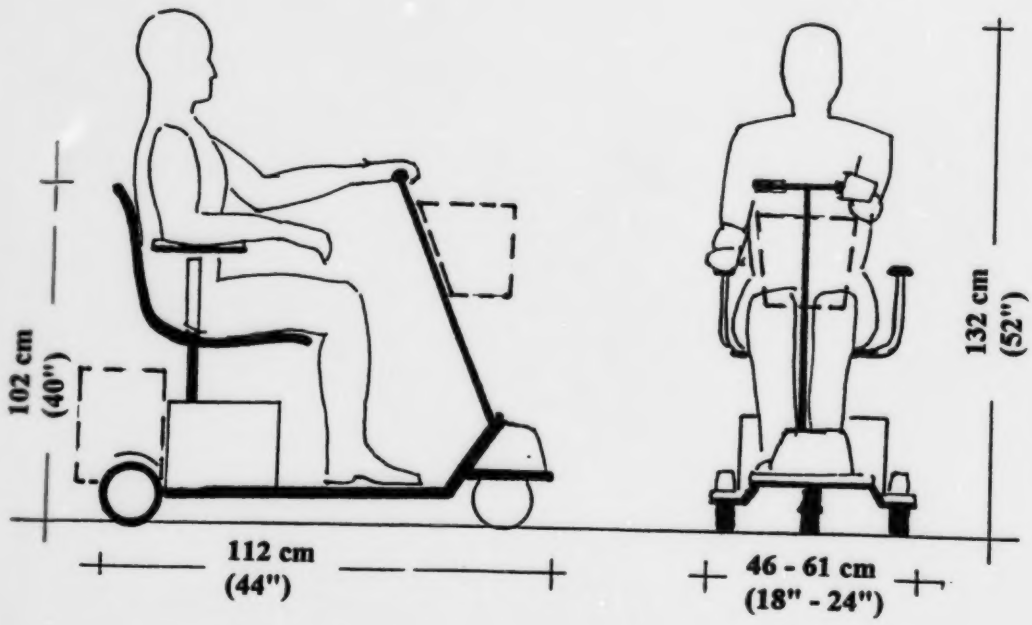
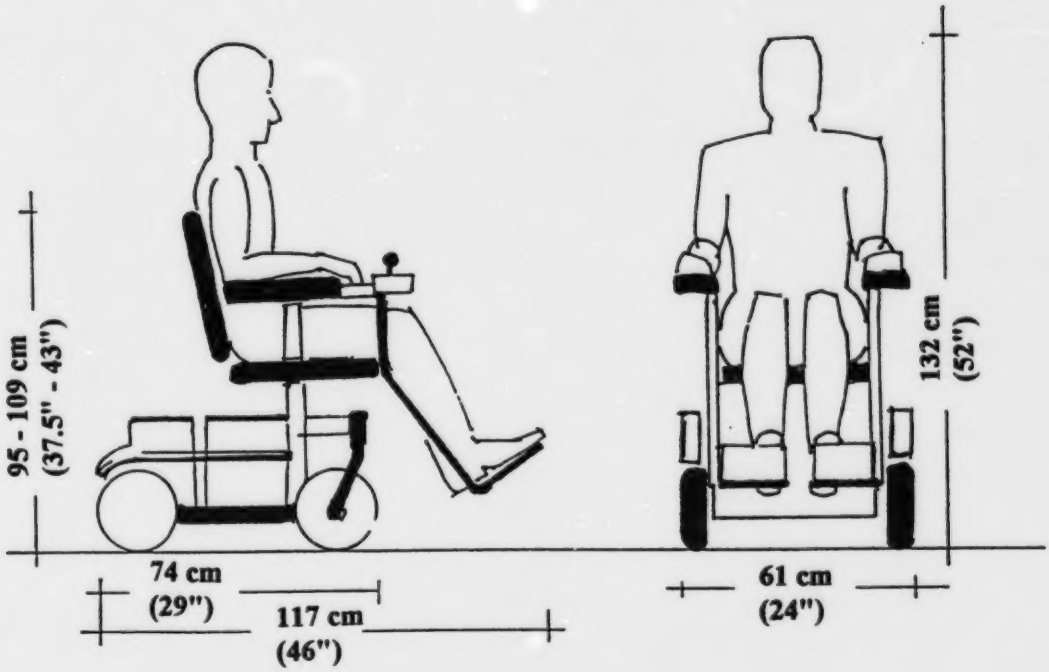


Fig 5. Electric power chair - four wheels
Battery powered; four small air-filled tires, two front wheels steering; joy-stick operated



2.3 Mobility aid envelopes

The dimensions shown here indicate the dimension for the mobility aid, not the person using the equipment.

	width x length x height of envelope in m (inches)	
Manual wheelchair	0.61 x 1.22 x 0.76	(24 x 48 x 30)
Sports wheelchair	0.71 x 1.22 x 0.76	(28 x 48 x 30)
Electric converted	0.61 x 1.22 x 0.81	(24 x 48 x 32)*
Electric powered 4 wheel	0.61 x 1.22 x 0.81	(24 x 48 x 32)*
3 wheel scooter	0.61 x 1.22 x 0.81	(24 x 48 x 32)* *
Arm crutches	0.91 x 0.56 x 0.51	(36 x 22 x 20)
Elbow crutches	0.76 x 0.56 x 0.51	(30 x 22 x 20)
Cane (1)	0.76 x 0.56 x 0.89	(30 x 22 x 35)
Canes (2)	0.91 x 0.56 x o.89	(36 x 22 x 35)
Walker		
when walking	0.71 x 1.12 x 0.89	(28 x 44 x 35)
when standing	0.71 x 0.68 x 0.89	(28 x 27 x 35)

Note:

* width can be greater, depending on size of additional equipment, e.g., wider seats, larger armrests, electrical equipment

* * length of scooter can be greater, depending on the size of front and rear baskets that are used

2.4 Passenger requirements

The target group includes mobility impaired passengers and their equipment, who are unable to negotiate stairs or have extreme difficulty doing so.

a) Wheelchair passengers using **manual wheelchairs** usually have good upper body strength to propel themselves and manoeuvre their wheelchair. They can often reach behind and down, and turn their upper body. Many have good strength in their arms and hands to pull, push and grip. They need little assistance, except for negotiating steep inclines. They can manoeuvre their wheelchair easily in tight spaces, including backing up. They can handle money exchange and insert coins into fare box.

b) Wheelchair passengers using **sports chairs** are usually persons with very good upper body strength, who are agile enough to bend, turn, reach up and down and behind their chair. They need no assistance, and many are active in sports. They can manoeuvre perfectly in a tight space, including backing up. They can handle money exchange and insert coins into fare box.

c) Wheelchair passengers using **electric converted wheelchairs** (large rear wheels with wider tires, small front casters) are usually persons with reduced upper body, arm and hand/finger strength and agility. Some people are unable to turn their head, or to reach up, down or behind. They can manoeuvre their wheelchair well, but backing up can be a problem if precise manoeuvring is required. They can push controls within their reach but cannot hook belts to their chair and tighten them. They may also have difficulty handling money/coin exchange and reaching to insert coins into the fare box.

d) Wheelchair passengers using **electric powered chairs** (four small wide air- filled tires) are usually persons with reduced upper body, arm and hand/finger strength and agility. Some are unable to turn their head, or to reach up or down or behind. They can manoeuvre their wheelchair well, but backing up can be a problem if precise manoeuvring is required. They can push controls within their reach but cannot hook belts to their chair and tighten them. They may also have difficulties handling money/coin exchange and reaching to insert coins into the fare box.

e) Wheelchair passengers using **three wheel scooters** are usually persons who have reduced body strength. Some can stand up and transfer from their scooters without help and many others use the scooter to compensate for longer walking distances. Some also use the scooter outdoors where they are not required to manoeuvre in restricted space. They usually have difficulties estimating turning and backing up in tight areas. Many outfit their scooters with front and rear baskets, which extends their space requirements and turning space. Some scooter designs have increased in size (length and width), because they are considered an excellent mobility aid for elderly persons in senior communities. Scooters have a stability problem along their longitudinal axis and can tip sideways on a transverse inclined surface. Scooters, especially when used by a heavy person can tip backwards on steep inclines due to the persons high centre of gravity. Scooter users can handle money exchange and insert coins into the fare box.

f) Mobility impaired passengers using **one cane** usually have stamina, strength and balancing difficulties. They require flat anti-slip surfaces without obtrusions in the floor. To gain access to and egress from a seat, they require a handgrip to lower their body into a seat and pull themselves out of a seat. Some, because of age, may have a stooped posture, and therefore need more space in front of a seat to get in and out and steady their cane. They can handle money exchange and insert coins into the fare box.

g) Mobility impaired passengers using **two canes** can have stamina, strength and balancing difficulties. They require flat anti-slip surfaces without obtrusions in the floor, and additional space on each side for their canes. They can handle money exchange and insert coins into the fare box. To access to and egress from a seat, they require a handgrip to lower their body into a seat and pull themselves out of a seat. Some, because of age, may have a stooped posture, and need more space in front of a seat to get in and out and steady their canes. They require a space to store their canes.

h) Mobility impaired passengers **using walkers** usually have stamina, strength and balancing difficulties. They require flat anti-slip surfaces without obtrusions in the floor, and additional space in front to advance the walker. Some can negotiate their walker sideways in tight spaces. To gain access to and egress from a seat they need additional space in front of the seat to place their walker, and a place to store it. They can handle money exchange and insert coins into the fare box.

i) Mobility impaired passengers using **arm crutches** usually have a temporary disability, e.g. from an accident. They require flat antislip surfaces without obtrusions in the floor, and a place to store their crutches when using a seat. They can usually stand up on one leg for a short time. They need additional space left and right to spread their crutches. They can handle money exchange and insert coins into the fare box.

j) Mobility impaired passengers using **elbow crutches** can have a temporary disability caused by an accident or an operation, or a permanent deterioration of muscular strength in their lower limbs. Some can walk with crutches for short distances and use a wheelchair for longer distances. They require flat antislip surfaces without obtrusions in the floor, and only a small additional space on each side for crutches. Many can negotiate their movement sideways and turn in tight quarters. They can handle money exchange and insert coins into the fare box.

3. ALTERNATIVE DESIGNS ADOPTED BY CANADIAN ACCESSIBLE TRANSIT SYSTEMS

3.1 Observation of adopted designs

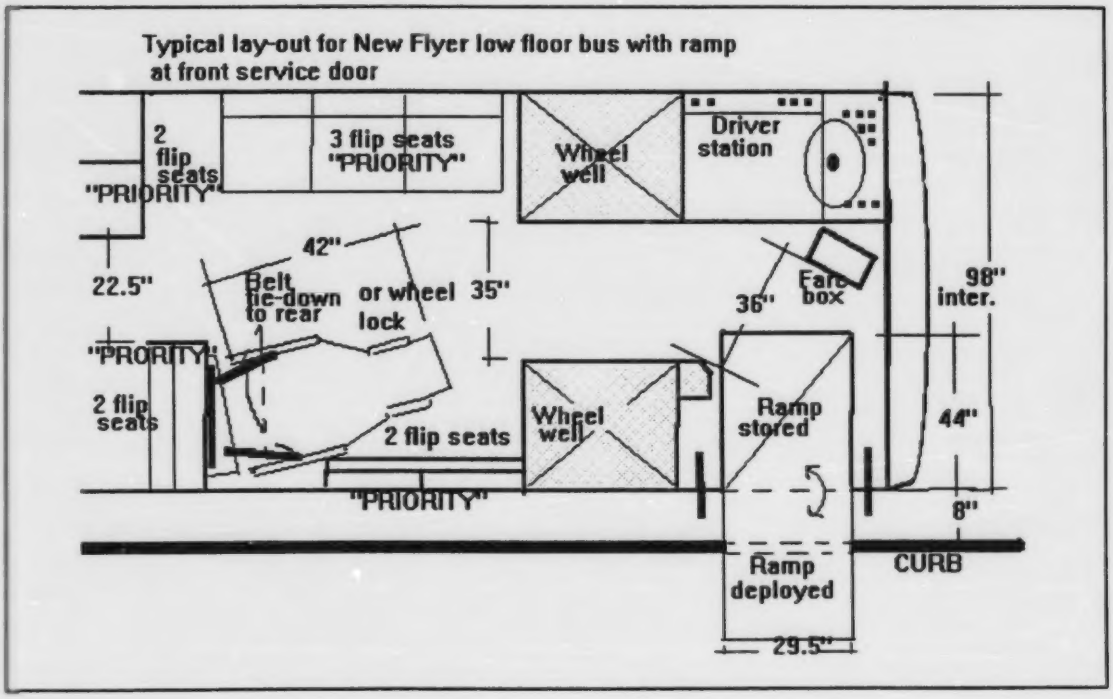
A survey of transit systems was undertaken in Victoria, Vancouver, Edmonton, Alberta and St. Albert in early 1994, through on-site visits. Of the five transit systems investigated, four were using low floor buses manufactured by New Flyer (Fig. 6). The fifth, Vancouver, was the first accessible transit system in Canada, and had at the time chosen to use lift equipped buses (Fig. 7).

All low floor buses are equipped with a hydraulic floating ramp installed at the front door, which can also be manually operated and be used by all passengers. The high floor bus is equipped with a lift and platform which can only be used by passengers in wheelchairs or scooters. All buses have a fare box mounted near the driver's seat where the passenger must insert the exact fare or show a pass. Proceeding from the fare box to the centre of the bus requires a turn of about 90 degrees, and an additional 180 degrees in the main traffic aisle for positioning the wheelchair to be secured. This can create interference with other passengers who are seated in the area. Most transit systems, except one, had two places for wheelchairs, which were designated at the same time as "Priority Seating" for disabled and elderly persons. These locations are on each side of the bus behind the front wheel wells. Two types of securements were found in use, the wheel-rim lock and the angled stop. Both require the use of belts and hooks and the help of an assistant/companion. Some transit systems provide lap belts for the wheelchair passenger, but their use is not mandatory for persons over 16 years old. Usually the driver is instructed to make sure that the wheelchair is secured, but should not assist in the deployment or disconnecting of belts. Some operators use a two-for-one fare, in which case the companion of the wheelchair passenger travels free, but is responsible for all operating tasks, e.g., flipping up seats, backing the wheelchair into position, deploying the belts etc. All wheelchair/scooter users face the driving direction in their travelling position. Requesting the bus to stop is achieved by various methods, pulling a cord, touching a sensitive strip, or pushing a button. To exit, the wheelchair passenger or his/her companion disconnects the belts, and the driver deploys the lift or ramp.

The major difference between the low floor and the lift equipped bus is the access mode to overcome the height difference between the road/curb and the bus floor. In a low floor bus a simple ramp achieves the objective; in the high floor buses in Vancouver, a lift with a platform is required.

A description of the specific designs adopted by the five observed transit systems is summarized in Tables 1 - 5.

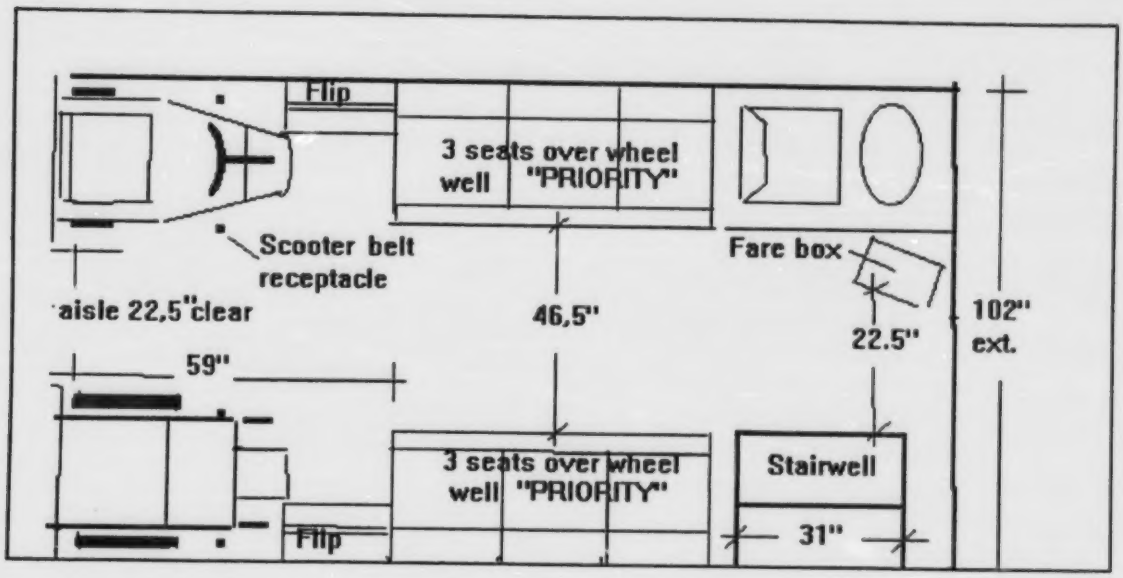
Fig. 6 Low floor bus with ramp at front door



"Priority" seats are reserved for persons with limited mobility

Schematic lay-out of a typical low floor bus equipped with a ramp at the front door. All flip seats are designated as "Priority" seating.

Fig. 7 Lift-equipped (high floor) bus



"Priority" seats are reserved for persons with limited mobility

Schematic drawing shows typical high floor bus equipped with lift, MCI or Flyer

Table 1
Accessibility design summary: BC Transit, Victoria

1. Type of bus	Low floor, New Flyer
2. Type of ramp	Hydraulic swing-out ramp at front door (30" wide and 44" long), manual swing-out if hydraulic fails. Ramp has bright yellow 2" high side guards and is covered with an antislip rubber/vinyl. The inclination of the ramp when placed on a 6" curb and bus is kneeled is approximately 1: 9 (6 degrees), and 1:4 (13 degrees) when placed on the road. When not kneeled, the ramp incline to curb is 1:6 (10 degrees), and to road 1:3 (18 degrees).
3. Access to bus	All passengers access through front door with an opening of 33"; bus kneeled: 11" to road, not kneeled: 14.6 " to road; if 6" curb, 5.6" and 8.6" respectively.
4. Egress from bus	Passengers egress through rear door, except for passengers with mobility aids, who egress through front door.
5. Type of securement	Angled rear stop mounted to double fold-up seat. Multiple position track; two tie-down belts attached to rear of wheelchair, must be tensioned by simple hand buckle. Securement prevents wheelchair from moving under normal driving and severe braking conditions, and up to 10g crash forces.
6. Securement for scooter	Two rear tie-down belts plus one front belt across foot rest area. Belts are stored in box behind driver
7. Type of passenger restraint	Lap belts mounted at fold-up bench for the wheelchair position.
8. Number of wheelchair positions per bus	Two wheelchair positions facing forward
9. Number of fold-up seats required per wheelchair position	4 left-hand side, 5 right-hand side
10. Identification of area reserved for mobility impaired passengers	Signs on seat, wall
11. Fare payment	Fare box 41" high, with remote dumping switch, floor mounted at front, near driver, payment by coin insert or showing pass
12. Transit policy	Companion for wheelchair passenger rides for free, if he/she handles securement/restraint and assists in manoeuvring. Driver is responsible for securement being applied, and is required to help as necessary. Lap belt is optional. Wheelchairs are tested for access; Those that fit receive access decals. Wheelchairs and scooters larger than this can not be transported due to restricted dimension between wheel cover and driver pedestal (36").
13. Seating capacity	Without wheelchair passengers: 38 seats with one wheelchair passenger: 34 with two wheelchair passenger: 30
14. Stop request	Pull-cord near window, or push button mounted on bar under side-facing seat at 27" high. Lit overhead display shows "Next Stop".

Table 2
Accessibility design summary: Calgary Transit

1. Type of bus	Low floor, New Flyer
2. Type of ramp	Hydraulic swing-out ramp at front door (29.5" wide and 40.3" long, newer models are 44.75" long), manual swing-out if hydraulic fails. Ramp has bright yellow 2" high side guards and is covered with an antislip paint. Additional heater supplies heat to platform area. The inclination of the ramp when placed on a 6" curb and bus is kneeled is approximately 1: 11 (5 degrees), and 1:4 (13 degrees) when placed on the road. When not kneeled the ramp incline to curb is 1:6 (10 degrees) and to road 1:3 (18 degrees).
3. Access to bus	All passengers access through front door, opening: 75.5" high x 31" wide; bus kneeled: 10.6" to road, not kneeled: 14.6 " to road; if 6" curb, 5.6" and 8.6" respectively
4. Egress from bus	All passengers egress through rear door, except for priority seating passengers (blind, frail, etc.) or those with mobility aids (strollers karts, etc.), who egress through front door
5. Type of securement	Angled rear stop mounted to double fold-up seat. Multiple position track; two tie-down ratchet belts attached to rear of wheelchair. When not in use, belt hooks are supposed to be connected to eye hooks under seat. Securement reduces wheelchair from movement under severe braking conditions.
6. Securement for scooter	One belt across seat area
7. Type of passenger restraint	no restraint.
8. Number of wheelchair positions per bus	Two wheelchairs, one on each side, both facing front.
9. Number of fold-up seats required per wheelchair position	5 for each wheelchair position
10. Identification of area reserved for mobility impaired passengers	Signs on seat, window.
11. Fare payment	Fare box 41" high at front, near driver, payment by coin insert or showing pass.
12. Transit policy	Companion for wheelchair passenger must pay, he/she must handle securement/restraint and assists in manoeuvring. Driver is not responsible for securement being applied, but can assist at his own choice. Driver must fold down seats. Wheelchairs with envelope of up to 24" x 48" are accepted. Wheelchairs and scooters larger than this can not be transported due to restricted dimension between wheel cover and driver pedestal (41").
13. Seating capacity	Without wheelchair passengers: 36 seats with one wheelchair passenger: 31 with two wheelchairs: 26
14. Stop request	Pull-cord near window, or push button mounted on bar under side-facing seat at 27" high. Lit overhead display shows "Next Stop".

Table 3
Accessibility design summary: Edmonton Transit

1. Type of bus	Low floor, New Flyer
2. Type of ramp	Hydraulic swing-out ramp at front door (30.5" wide and 44.5" long, newer models are 44.75" long), manual swing-out if hydraulic fails. Ramp has bright yellow 2" high side guards and is covered with an antislip material. The inclination of the ramp when placed on a 6" curb and bus is kneeled is approximately 1: 11 (5 degrees), and 1:4 (13 degrees) when placed on the road. When not kneeled, the ramp incline to curb is 1:6 (10 degrees) and to road 1:3 (18 degrees).
3. Access to bus	All passengers access through front door; kneeled: 10.6" to road, not kneeled: 14.6 " to road; if 6" curb, 5.6" and 8.6" respectively.
4. Egress from bus	All passengers egress through rear door, except for passengers with mobility aids, who egress through front door.
5. Type of securement	Wheel rim lock mounted under double fold-up seat. Two retractable rear tie-down belts mounted underneath double folded seat. Two belts are used to secure front of wheelchair.
6. Securement for scooter	Two retractable rear tie-down belts mounted underneath double folded seat. Two belts are used to secure front of scooter.
7. Type of passenger restraint	Lap belts mounted underneath double fold-up seat.
8. Number of wheelchair positions per bus	Two wheelchairs, one on each side, both facing front.
9. Number of fold-up seats required per wheelchair position	4 and 5, five seats for longer space.
10. Identification of area reserved for mobility impaired passengers	Signs on seat, window
11. Fare payment	Fare box 46" high on pedestal at front, near driver, payment by coin insert or showing pass.
12. Transit policy	Companion for wheelchair passenger does not ride for free, if he/she handles securement/restraint and assists in manoeuvring. Driver is responsible for securement being applied, but is not required to help. Lap belt is not mandatory for persons over 16 years old.
13. Seating capacity	Without wheelchair passengers: 39 seat with one wheelchair passenger: 35 or 34, depending which space is used. with two wheelchairs: 30 seats
14. Stop request	Pull-cord near window, and push button mounted on bar under side-facing seat at 27" high. Lit overhead display shows "Stop requested".

Table 4
Accessibility design summary: St. Albert Transit

1. Type of bus	Low floor, New Flyer
2. Type of ramp	Hydraulic swing-out ramp at front door (29.5" wide and 40.3" long, newer models are 44.75" long), manual swing-out if hydraulic fails. Ramp has bright yellow 2" high side guards and is covered with an antislip rubber/vinyl. The inclination of the ramp when placed on a 6" curb and bus is kneeled is approximately 1: 11 (5 degrees), and 1:4 (13 degrees) when placed on the road. When not kneeled, the ramp incline to curb is 1:6 (10 degrees) and to road 1:3 (18 degrees).
3. Access to bus	All passengers access through front door; kneeled: 10.6" to road, not kneeled: 14.6 " to road; if 6" curb, 5.6" and 8.6" respectively.
4. Egress from bus	All passengers egress through rear door, except for passengers with mobility aids, who egress through front door.
5. Type of securement	Wheel lock mounted to double flip up seat, two floor-mounted Q-Straint belt brackets. Two belts are used to secure front of wheelchair
6. Securement for scooter	Two rear tie-down belts plus one front belt across foot rest area. Belts are stored in box on wheel well.
7. Type of passenger restraint	Lap belts mounted to fold-up bench.
8. Number of wheelchair positions per bus	Two wheelchairs, one on each side, both facing front.
9. Number of fold-up seats required per wheelchair position	4 and 5, five seats for larger space.
10. Identification of area reserved for mobility impaired passengers	Signs on seat, wall.
11. Fare payment	Fare box 41" high at front, near driver, payment by coin insert or showing pass.
12. Transit policy	Driver will provide assistance if requested. Driver checks securement.
13. Seating capacity	Without wheelchair passengers: 39 seats with one wheelchair passenger 33 or 32, depending which space is used. with two wheelchairs; 28 seats.
14. Stop request	Pull-cord near window, or push button mounted on bar under side-facing seat at 27" high. Lit overhead display shows "Next Stop".

Table 5
Accessibility design summary: BC Transit, Vancouver

1. Type of bus	Lift-equipped (high floor), New Flyer, MCI
2. Type of ramp	Hydraulic scissor lift with platform, built into front door's lower step. Platform lands on curb or road surface and has front and rear barrier to prevent wheelchair from rolling off. Handrails on both sides of platform for a standing person. The lift platform has sensitive edges which if touched by a passenger or other object will halt the movement of the lift immediately.
3. Access to bus	All passengers access through front door over three steps, except mobility impaired who use lift.
4. Egress from bus	All passengers egress through rear door, except for passengers with mobility impairments who egress through front door by the stairs or the lift.
5. Type of securement	Wheel rim lock plus two rear retractable belts, mounted under seat. One or two belts can be used in addition to wheel lock. Securement prevents wheelchair from moving under normal driving and severe braking conditions.
6. Securement for scooter	Two rear retractable belts (as in item 5 above) plus one front belt secured to bus floor across scooter foot platform. Scooter belts stored in box behind driver.
7. Type of passenger restraint	One lap-belt for each wheel-chair/scooter passenger attached to seat support under fold-up bench seat.
8. Number of wheelchair positions per bus	Two wheelchairs, one on each side, both facing front.
9. Number of fold-up seats required per wheelchair position	3 for each wheelchair/scooter position
10. Identification of area reserved for mobility impaired passengers	Signs on wall and window
11. Fare payment	Fare box 41" high at front, near driver, payment by coin insert, FareSaver tickets, or showing pass.
12. Transit policy	BC Transit provides a photo identity upon application from a passenger who is eligible for HandyDART and who wishes to use accessible buses. This card entitles the holder to concession fares on buses, SkyTrain, and SeaBus, and allows an accompanying attendant to ride free. The bus operator must attach the securement belts if the passenger or attendant cannot do so. The bus operator must not move the bus until he ensures a wheelchair or scooter is properly secured. The driver will also fasten the lap belt, which is not mandatory, if the passenger requests it. The lift size is 73 cm wide by 122 cm long (29 inches by 48 inches) and this is the maximum of mobility aid which can be accommodated. Maximum weight of mobility aid and passenger on the lift is 273 kg or 600 pounds.
13. Seating capacity	Without wheelchair passengers: 41 seats; with one wheelchair passenger: 38 seats; with two wheelchairs: 35 seats
14. Stop request	Pull-cord near window, or yellow touch sensitive bar under window on the wall beside each wheelchair position. Lit overhead display shows "Next Stop".

3.2 Securement types and passenger restraints in Canada

Most Canadian transit buses use one of two securement systems, the wheel-rim clamp and the angled stop. Both immobilize the wheelchair with belts and hooks which are attached from two rear anchor points to the rear or front of the wheelchair frame. These systems provide a level of safety which prevents the wheelchair from becoming loose under regular driving conditions, including severe braking and cornering. Both systems were discussed in detail in the previous chapter.

Passenger restraint

Both systems provide a passenger lap restraint system, consisting of two parts, a retractable buckle belt and a retractable tongue belt located at each side of the securement. The belts must be pulled out of their respective positions and are connected in the lap of the passenger. Use of the belt system is not mandatory for persons over 16 years of age.

The following pages show in schematic drawings how each system is applied for different wheelchair types. Figures 8 - 13 present the wheel-rim lock securement system, and Figures 14-19 present the angled securement system.

In addition, Appendices A and B provide detailed photographic logs of persons in wheelchairs and scooters boarding and positioning themselves on board the buses. This will help to visually illustrate how these systems are used.

Table 6 summarizes the implications of the two securement/restraint system used in Canada for the users of the 5 basic type of mobility aids.

Fig. 8 Wheel - Rim Lock Securement, System Components

1. Flip seat
2. Release for flip seat
3. Wheel rim lock
4. Wheel stop
5. Retractable tie-down belts for wheelchair, one each side
6. Passenger restraint belts, one each side
7. Front tie-down belt for three-wheel scooter
8. Floor anchors

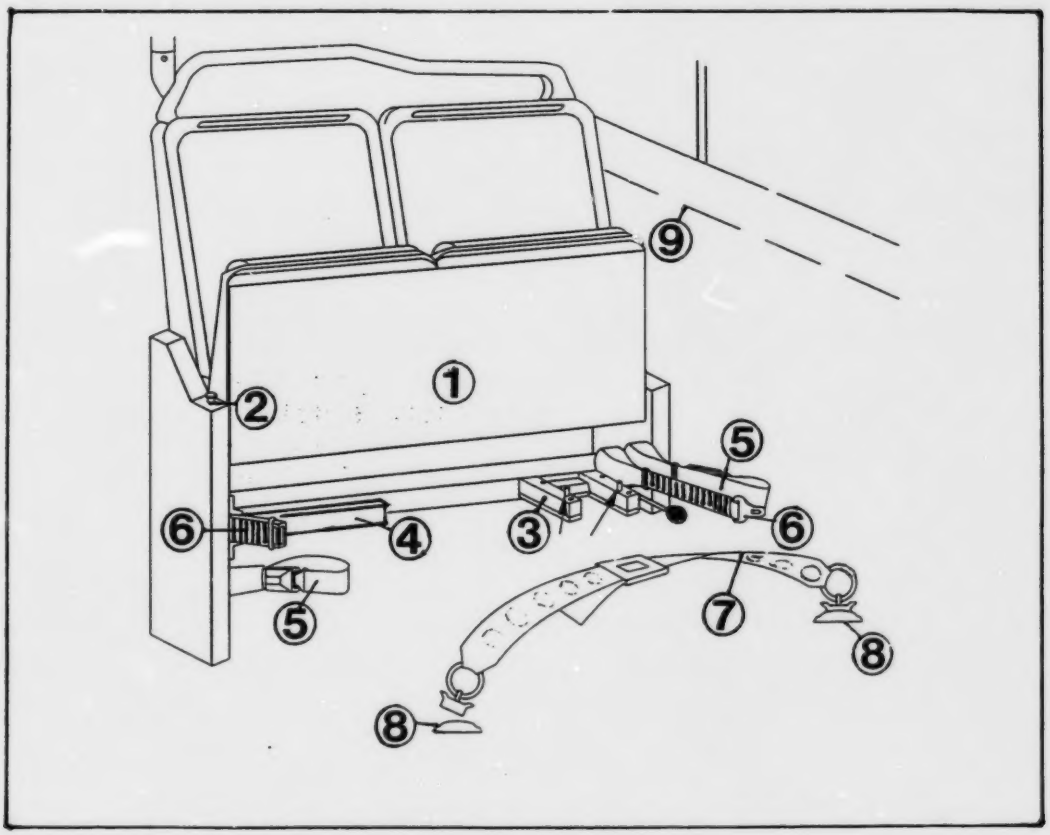


Fig 9 Wheel-Rim Lock:
Electric converted wheelchair

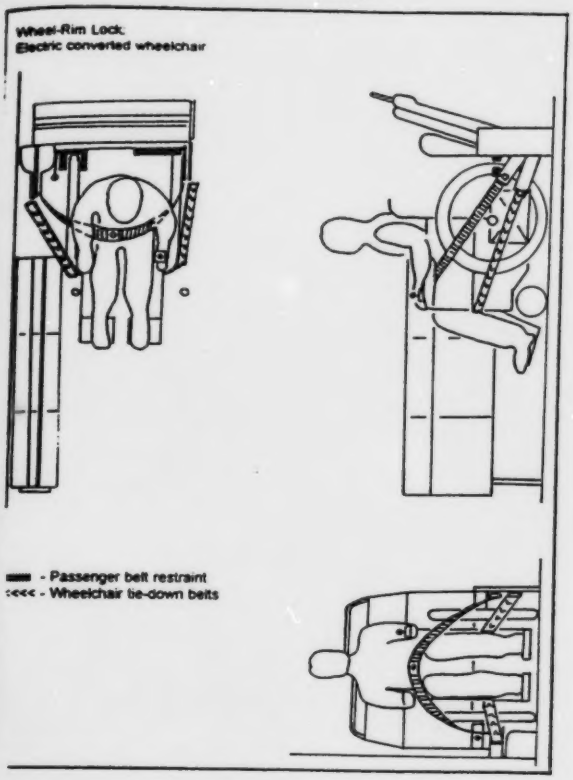
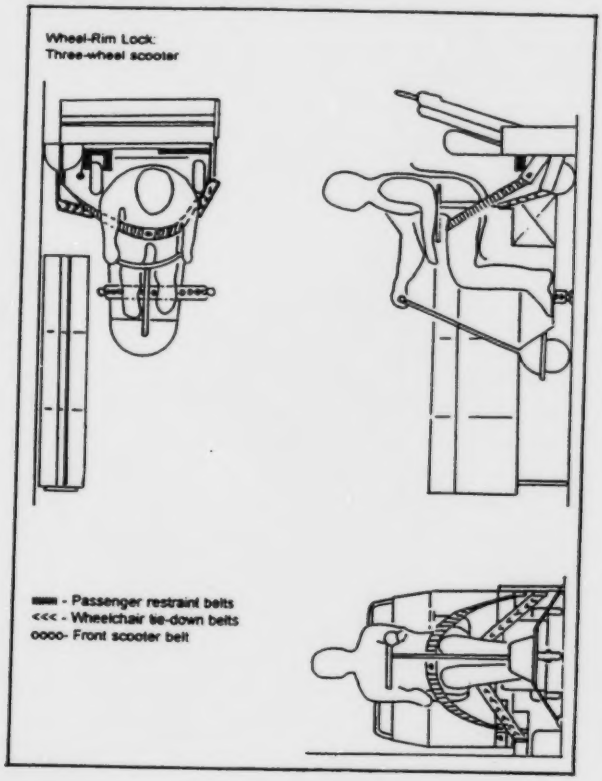
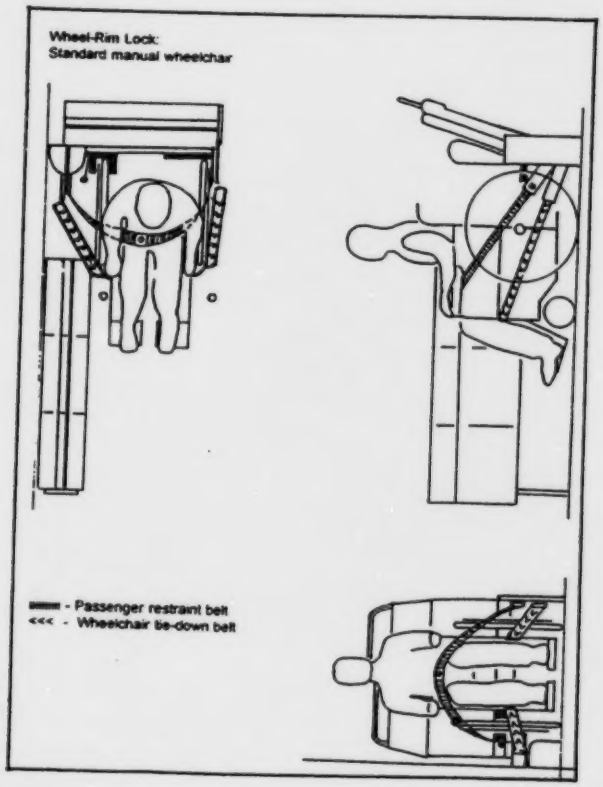


Fig 10 Wheel-rim Lock:
Three-wheel scooter





11 Wheel-Rim Lock:
ndard manual wheelchair

Fig 12 Wheel-Rim Lock:
Electric power chair - four wheels

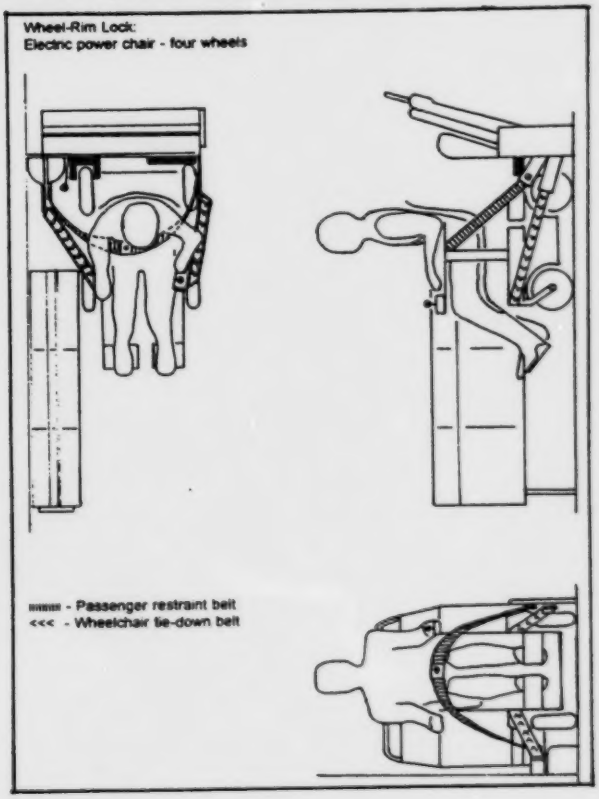


Fig 13 Wheel-Rim Lock:
Manual sports chair

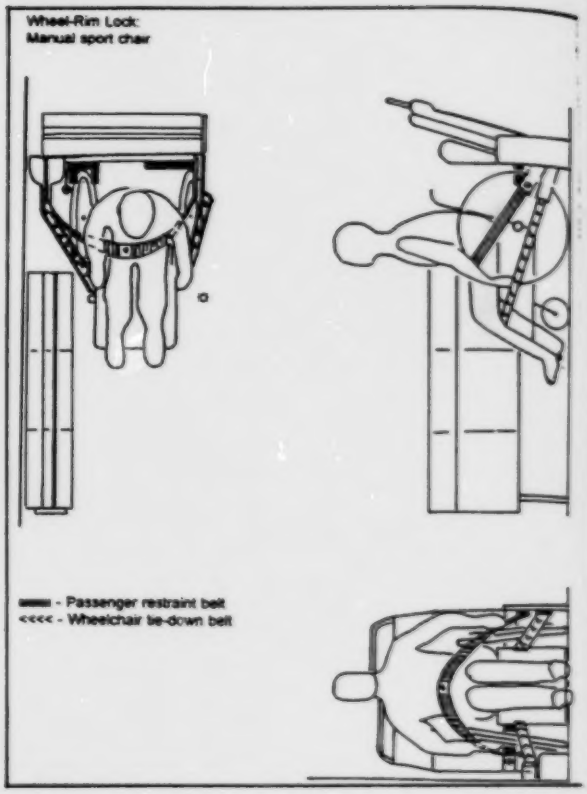


Fig. 14 Angled Securement: System Components

1. Flip seat
2. Flip seat release
3. Rear tie-down belts for wheelchair (2)
4. Multi-position track
5. Passenger restraint belts, one each side
6. Angled wheel stop
7. Front tie-down belt for three-wheel scooter
8. Floor anchors

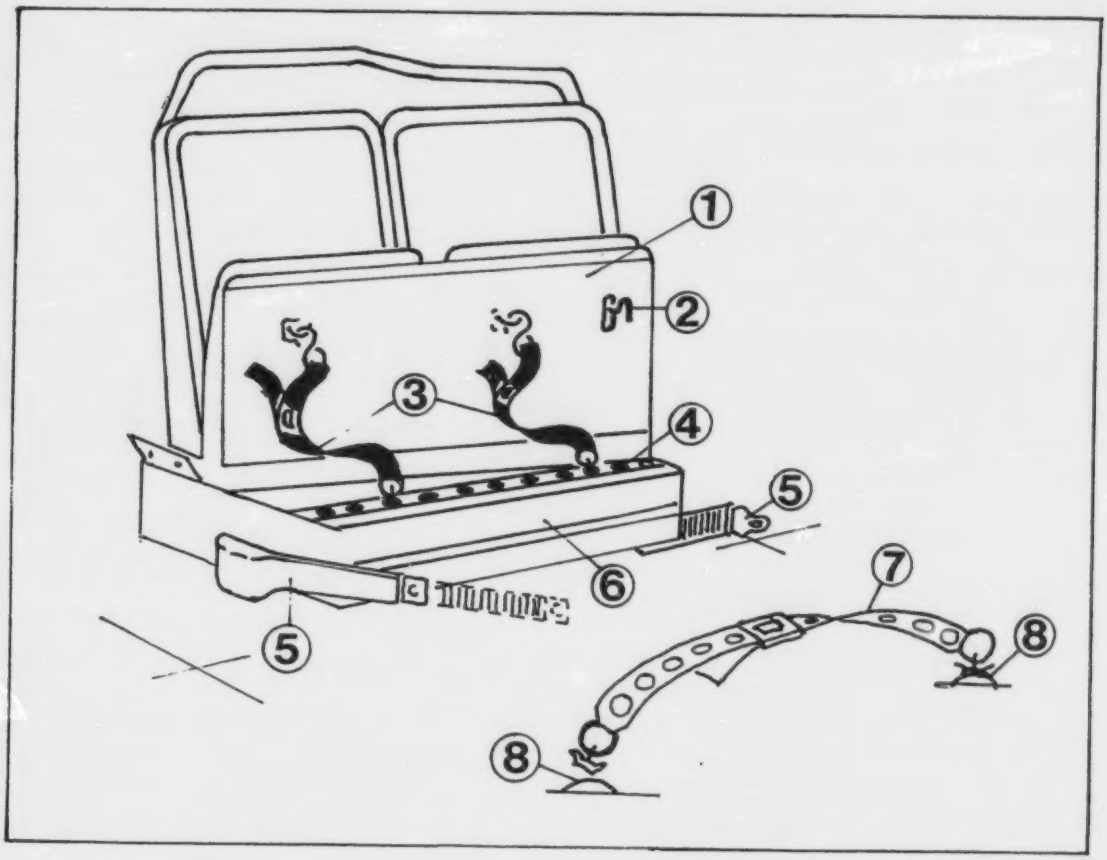


Fig 15 Angled Securement:
Three-wheel scooter

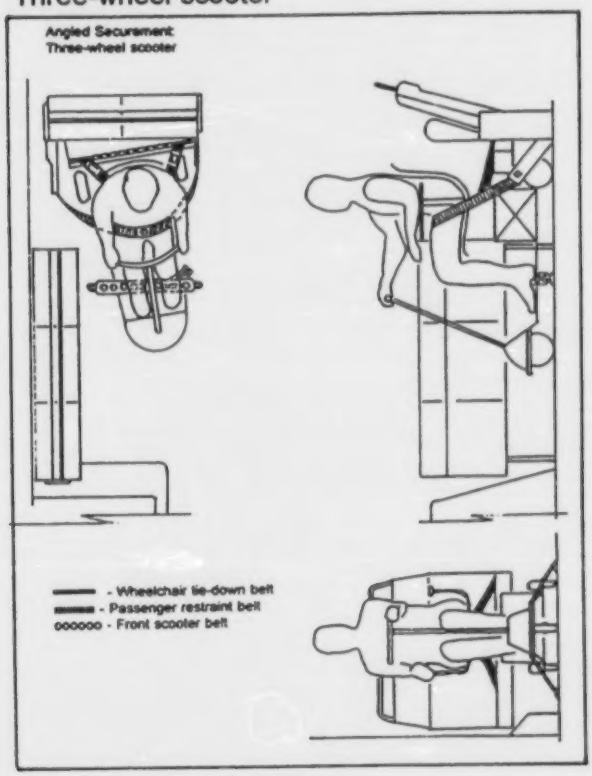
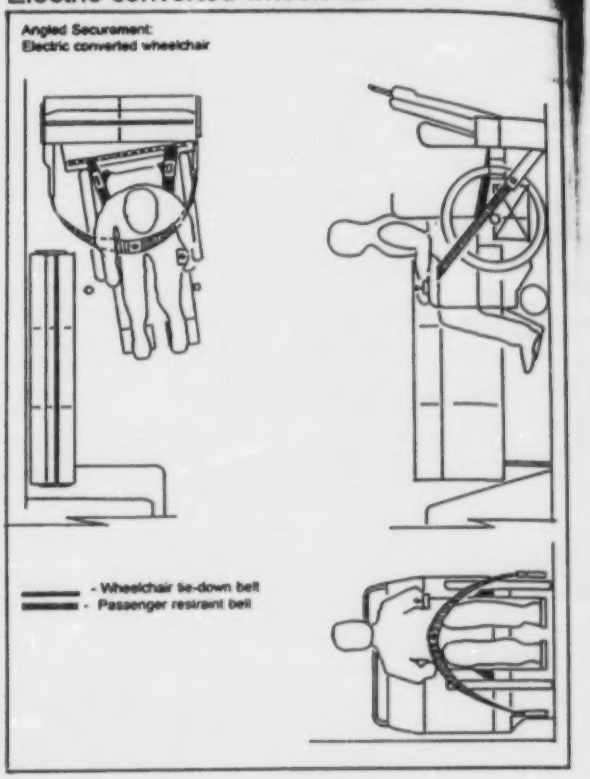


Fig 16 Angled Securement:
Electric converted wheelchair



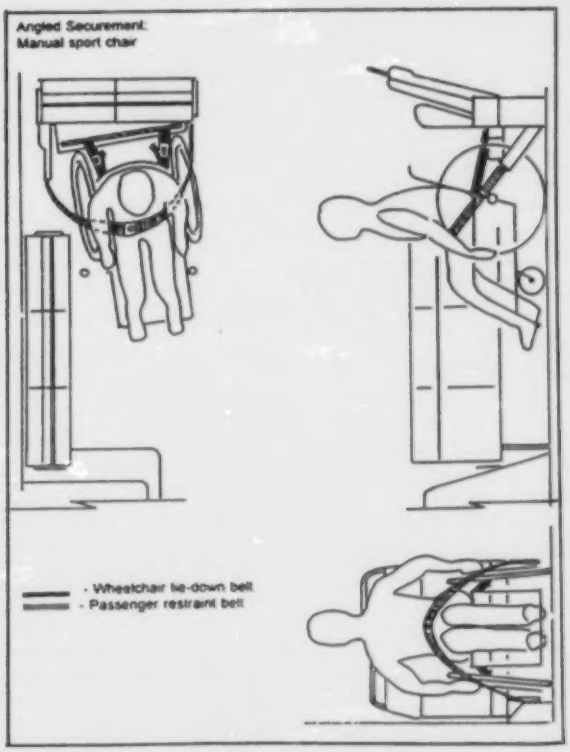


Fig 17 Angled Securement
Manual sports chair

Fig. 18 Angled Securement: Manual standard wheelchair

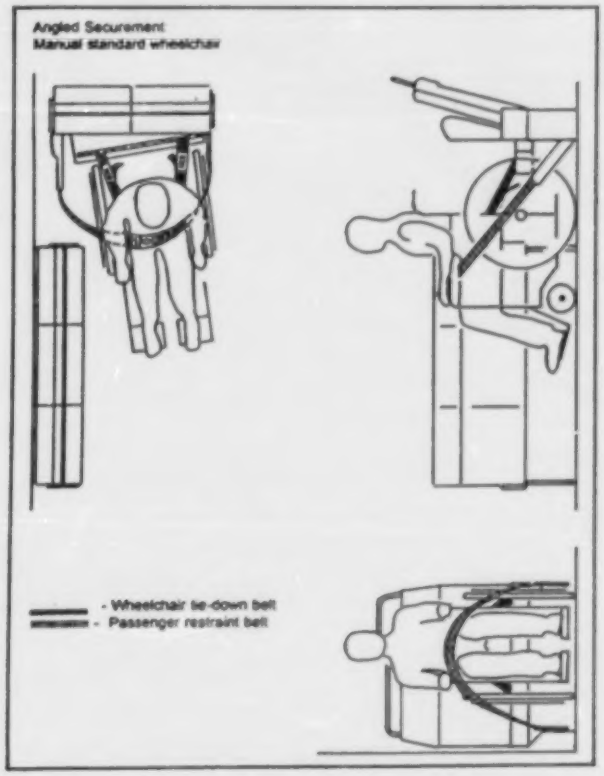


Fig. 19 Angled Securement: Electric power chair - four wheels

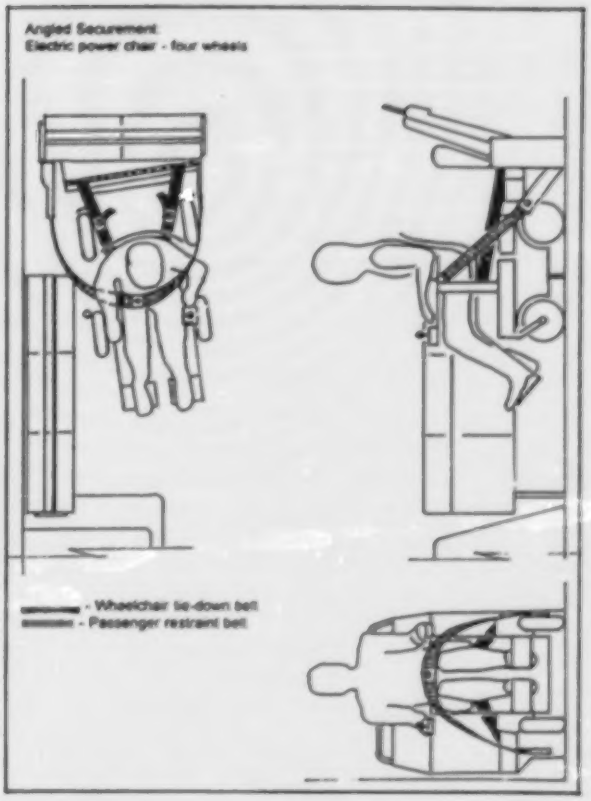


Table 6
Summary - Securement/restraint systems used in Canada

Wheelchair type	Angled Securement		Wheel-Rim Lock	
	Tie-down	Passenger restraint	Tie-down	Passenger restraint
Manual standard	Most passengers cannot reach belts behind chair, attach or detach belts; they require assistance	Most passengers cannot reach down to get belts; they require assistance	Not all passengers can reach for belts to attach/detach ,or for release lever; require assistance	Some passenger scan reach belts and buckle up; others need assistance
Sports chair	Most passengers can reach behind and attach/detach belts	Most passengers can reach belts and buckle up, because seat is positioned lower and passenger may have greater upper body mobility to reach back and down	Cambered rear wheel and hand rim do not always fit into rim lock; passenger can reach and attach/detach belts	Passenger usually can reach belts and buckle up
Electric converted	Passengers cannot reach behind and attach/detach belts; they require assistance	Passengers cannot reach down to get belts or buckle up; they require assistance	Wide air-filled tires require precise manoeuvring to fit rim lock ,opening of clamp is tight; most passengers are not able to turn head to back up chair into lock and cannot reach belts and release lever; assistance required	Most passengers cannot reach belts and buckle up; they need assistance
Three-wheel scooter	No designated attachment points on scooter; passenger cannot reach to attach rear or front belt; passenger must make certain to clear floor anchors for front belt; assistance required	Some passengers can reach down to get belts, others require assistance	Small rear wheels do not reach rim lock; rear of scooter housing comes in direct contact with metal seat structure; no designated points on scooter to attach rear belts; passenger cannot reach rear or front belts; passenger must make certain to clear floor anchors for front belt; assistance required	Some passengers can reach belts and buckle up; others require assistance
Electric powered chair	Passenger cannot reach behind to attach/detach belts; assistance required	Passengers cannot reach to get belts , nor buckle up; require assistance	Small rear wheels do not reach rim lock; passenger cannot reach belts and release lever; assistance required; rear of chair housing comes in direct contact with metal seat structure	Most passengers cannot reach belts and buckle up; assistance is required

Other securements in North America

Other securements investigated include the 4-point wheelchair securement with a 3-point passenger restraint systems used in the US, the Independent Locking System (ILS), and the Cleveland prototype harness.

Securements used in the US for transit buses must comply with the ADA legislation and require that 2 front and 2 rear legs are anchored to the floor and connected to the frame of the wheelchair/scooter with determined loadings for each leg. In addition, a lap and shoulder belt are required for the wheelchair passenger with determined loadings for each anchor point (Fig. 20 and Fig. 21).

The Independent Locking System (ILS) has just recently been introduced to the market and consists of two major elements, a horizontal securement box on a vertical post mounted to the floor, and two vertical D rings connected to the rear of a wheelchair. The two D rings are mounted to the wheelchair/scooter via interface brackets. The securement box is about 25 cm (10") above the floor and has two "V" openings facing the rear of the wheelchair. The wheelchair with the D rings backs up into the V openings and a mechanism automatically locks the rings. The unlocking of the mechanism is done mechanically or electrically (Fig. 22 and Fig. 23). A number of these systems are presently being tested and evaluated by various operators in Canada and the US. An additional passenger restraint system is available with two retractable belts mounted on the side of the securement box and a shoulder belt mounted to the bus wall.

The Cleveland securement prototype is presently under development and consists of a two-prong harness with one pair of ends manually connected to the rear frame of the wheelchair and the other pair joining in an interface (Fig. 24). Once the flexible prongs are connected to the wheelchair frame and stiffened, the wheelchair can back into a floor mounted latch, where the interface is locked. The system is operated by the driver and is in his custody.

Fig. 20 Four point belt system (US)
(US - ADA compliance)

1. Multi-position floor track (rear)
2. Multi-position floor track (front)
3. Passenger lap belts
4. Wheelchair tie-down belts
5. Tie-down belt for battery operated wheelchairs
6. Shoulder harness
7. Front tie-down belts

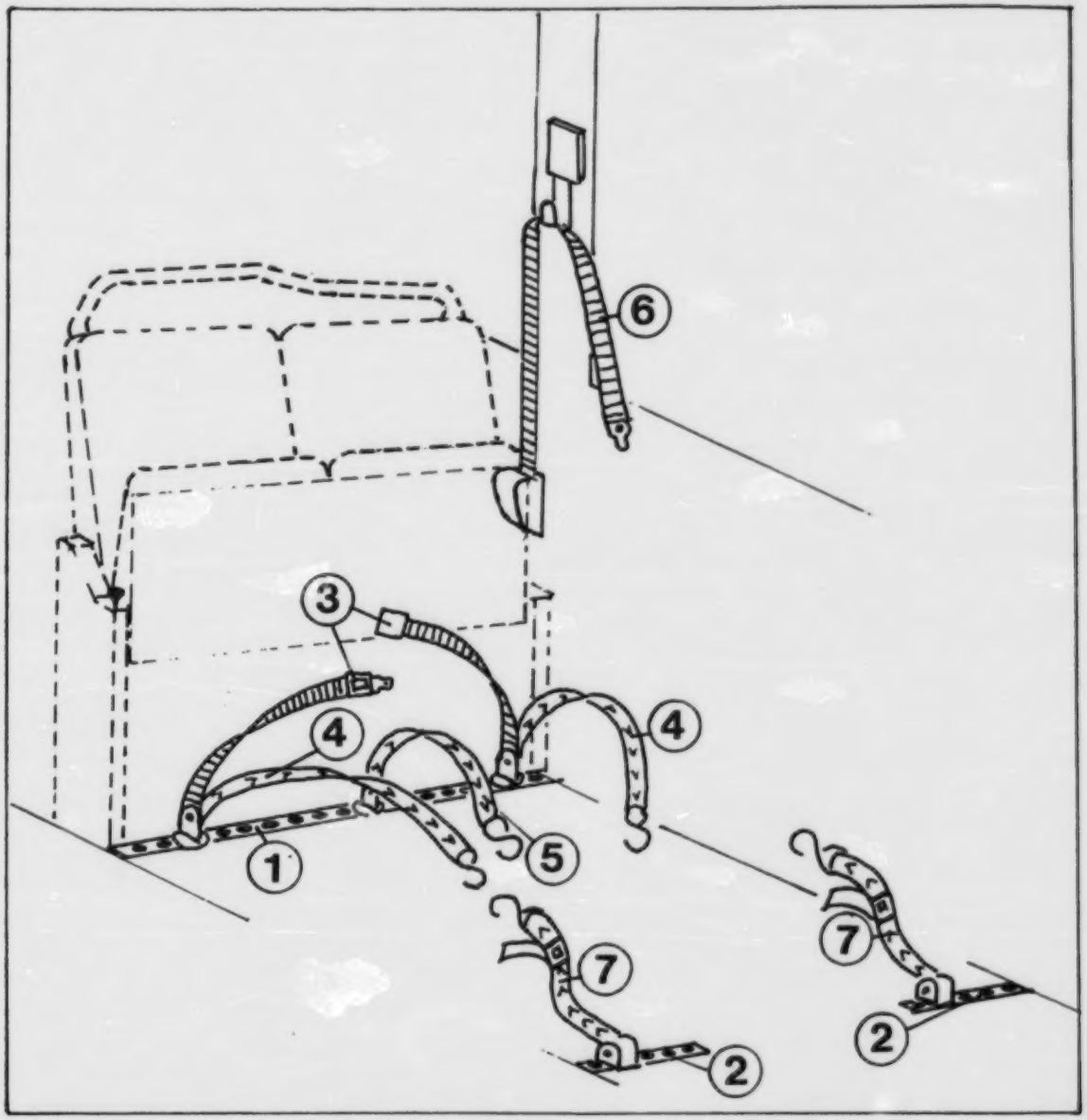
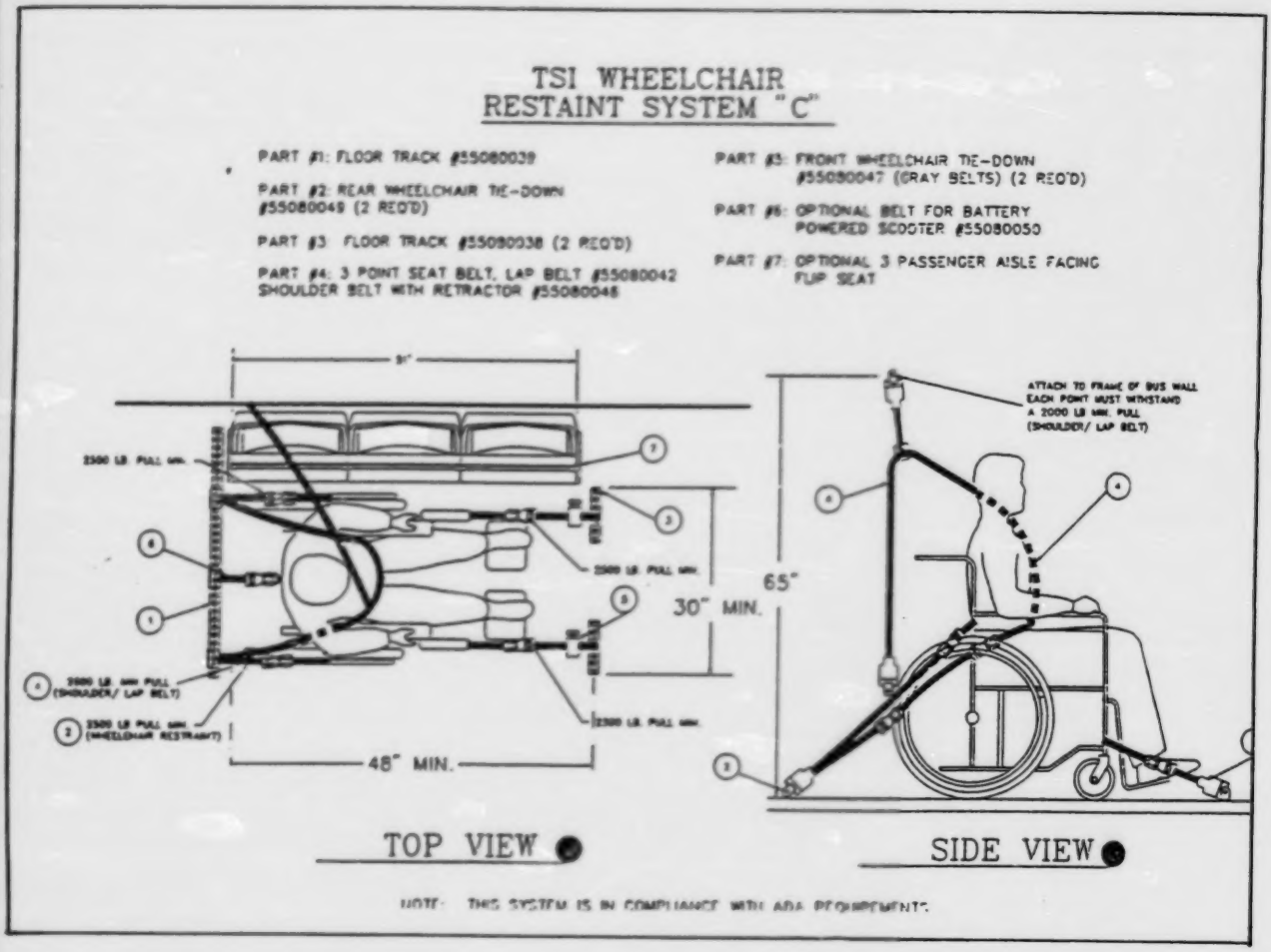


Fig. 21 Four point belt securement: manual wheelchair


TSI WHEELCHAIR
RESTAINT SYSTEM "C"
PART #1: FLOOR TRACK #55080039
PART #2: REAR WHEELCHAIR TIE-DOWN #55080049 (2 REQ'D)
PART #3: FLOOR TRACK #55080038 (2 REQ'D)
PART #4: 3 POINT SEAT BELT, LAP BELT #55080042 SHOULDER BELT WITH RETRACTOR #55080048
PART #5: FRONT WHEELCHAIR TIE-DOWN #55080047 (GRAY BELTS) (2 REQ'D)
PART #6: OPTIONAL BELT FOR BATTERY POWERED SCOOTER #55080050
PART #7: OPTIONAL 3 PASSENGER AISLE FACING FLIP SEAT
2500 LB PULL MIN.
30" MIN.
65"
48" MIN.
ATTACH TO FRAME OF BUS WALL EACH POINT MUST WITHSTAND A 2000 LB MIN. PULL (SHOULDER/ LAP BELT)
TOP VIEW
SIDE VIEW
NOTE: THIS SYSTEM IS IN COMPLIANCE WITH ADA REQUIREMENTS.

This system is produced by Transportation Seating Inc., Montezuma, Georgia (U.S.)

Fig. 22 Independent Locking System

1. Securement housing
2. Latching mechanism (2) with guide slots
3. Lap belts (2)
4. Shoulder harness
5. Manual release (2)
6. Electrical control to release latching
7. Wheelchair interface
8. Steel D-rings

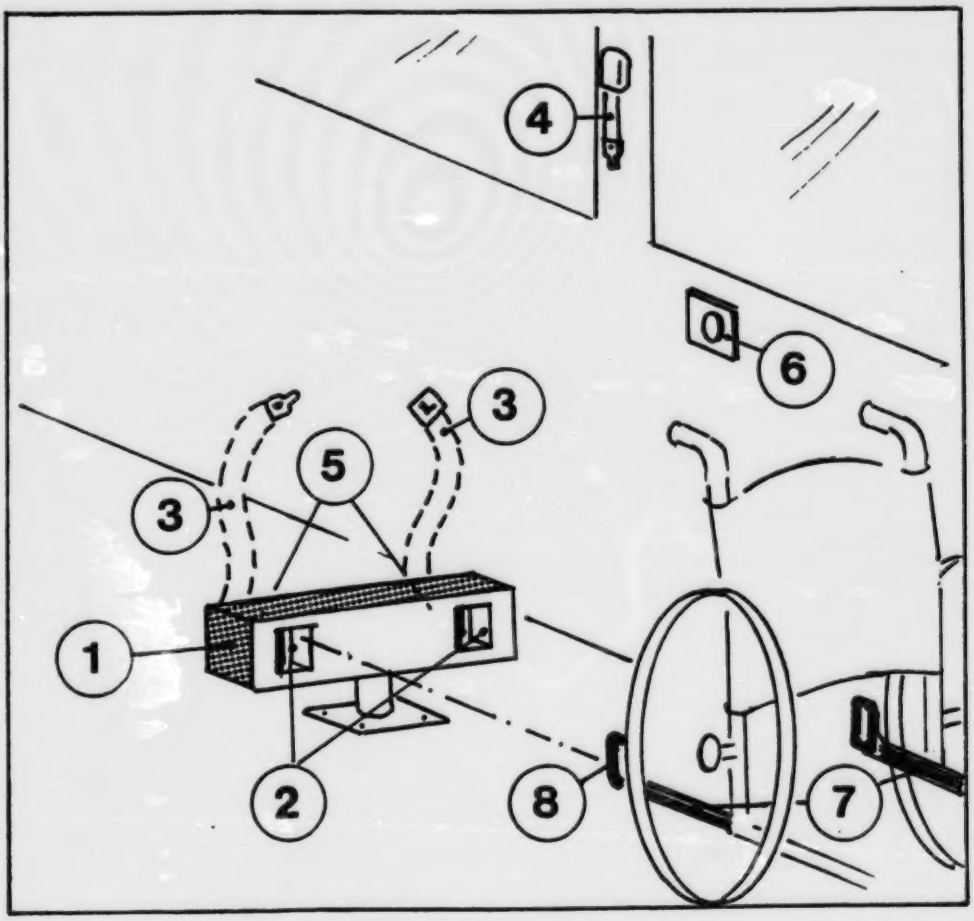


Fig. 23 Independent Locking System: standard manual wheelchair

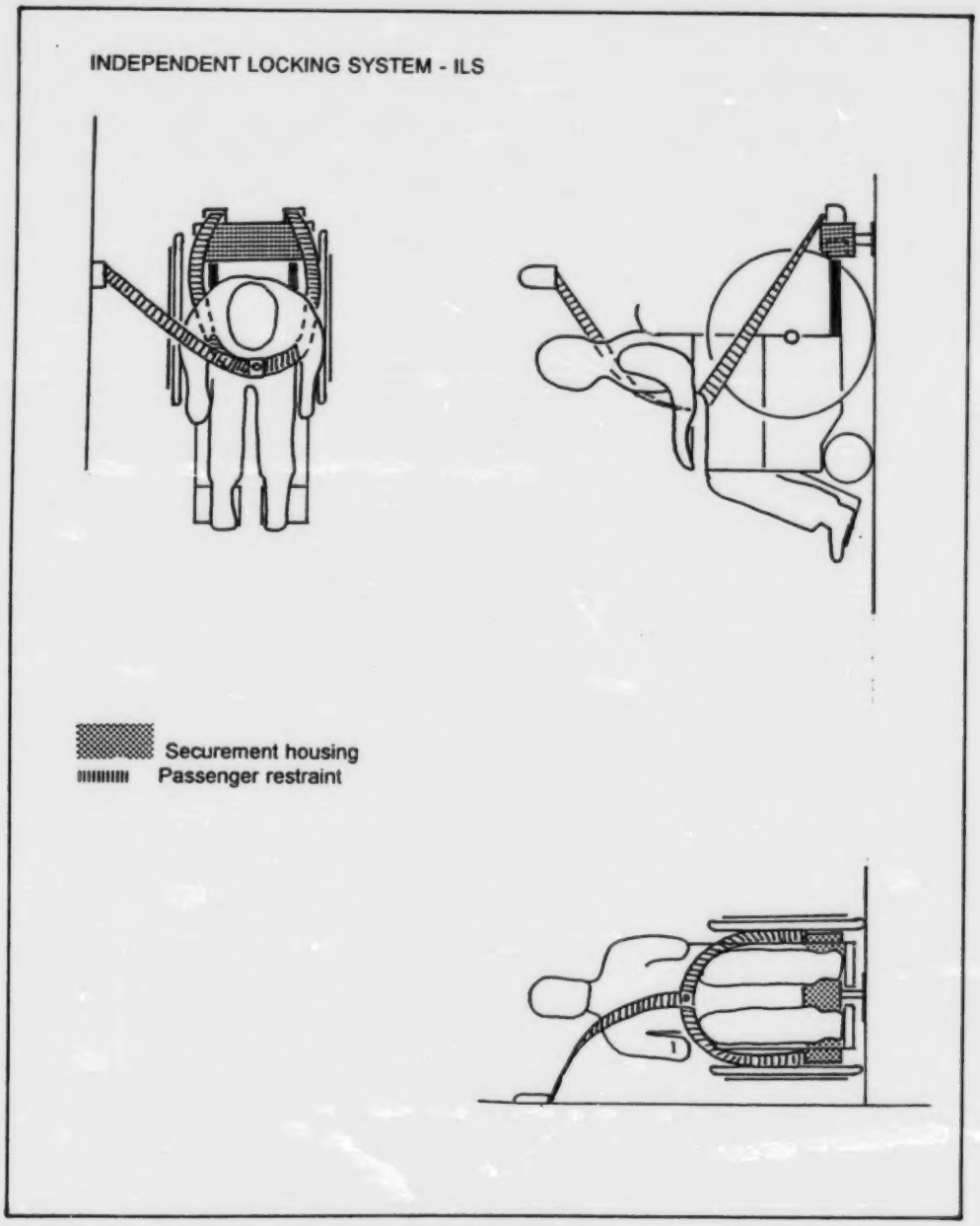
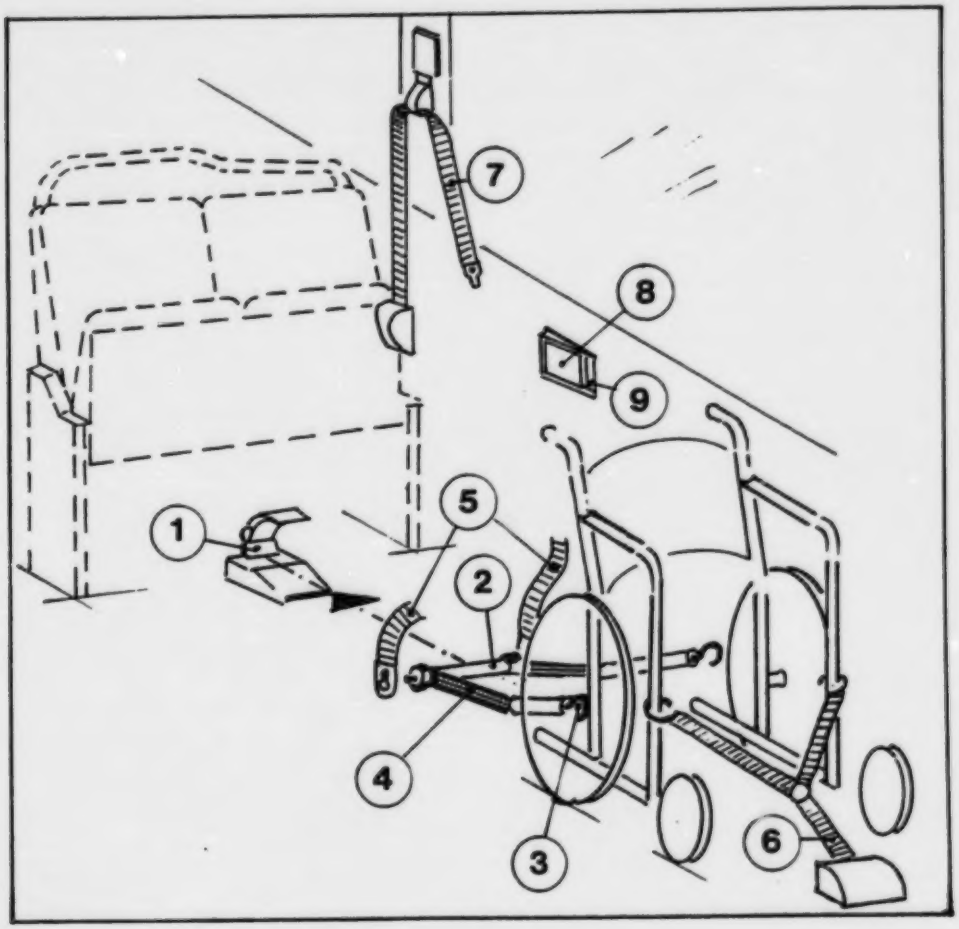


Fig. 24 Cleveland securement system (prototype)

1. Floor mounted docking latch
2. Interface (different for scooters)
3. Hooks to wheelchair frame
4. Turnbuckles to tighten/loosen harness
5. Passenger lap belts
6. Floor mounted front belt
7. Shoulder belt
8. Lever to release latch
9. Front belt lock



4. FOREIGN RESEARCH

4.1 European Research

The issue of safety standards and wheelchair securements in low floor buses is an international issue. Several countries are involved in research efforts to solve this problem.

Germany was one of the very earliest countries involved in the development and implementation of accessible low floor buses. Research conducted in 1990-92 by the Ministry of Transport, in cooperation with transit systems, provided some valuable insights into the accommodation of wheelchairs on buses [6]. Appendix C provides detailed summaries of two research efforts that were particulary relevant.

With the introduction of low floor buses, it was recognized that the opportunity to make transit buses accessible for wheelchair passengers increased significantly. This results in the question of whether or not the safe transport of wheelchair passengers requires special measures in transit buses, and what is necessary to secure/restrain wheelchair passengers.

To answer this question three studies were undertaken, two of which are relevant to transit buses. The first study by BASt (German Federal Highway Research Institute) carried out deceleration tests with a manual and an electric wheelchair placed unsecured on a moving test platform each loaded with a dummy. The objective was to establish the acceleration and deceleration forces which occur to bring a wheelchair passenger into an unsafe situation without using a securement system.

To complement the first study, tests were carried out by STUVA (Research Commission for Underground Traffic Installations) to analyze which acceleration/deceleration forces are experienced by a manual and electric wheelchair in a transit bus under normal operating conditions in a city.

The conclusion of these two studies indicate that it is possible to transport wheelchair passengers in a transit bus **safely without a securement/restraint system**, provided that:

there is a "confined space" for a wheelchair passenger with a back-support panel,

- the wheelchair passenger is facing rearwards with the wheelchair back in contact with the back support,
- the wheelchair brakes are firmly applied,
- the driver exercises reasonable driving habits
- the speed does not exceed city speed limits

As a result of this research, a number of German transit systems have developed a "protected position" design for accommodating mobility aids on board full size buses.

This design fulfils the above mentioned requirements and is being used in the cities of Essen, Berlin, Bremen, Cologne and Aachen.

In **England**, this "protected position" design has been further refined, and has been demonstrated in London since early 1994 in a project co-sponsored by the British Department of Transport and London Transport. More detailed information and photos are provided in Appendix D from an article published in CUTA Forum [24]. Access for the general public is through the front door and wheelchairs and scooters enter over an extendable ramp at the centre door. Use of the ramp must be requested by passengers who must push a button on the outside of the bus. Passengers using crutches, canes or walkers can request the use of the ramp at the centre door or board at the front door. The ramp is built into the bus, extending about 60 cm (24") over the sidewalk and operated by the driver. Sensors will stop the ramp operation if an obstacle, e.g. passenger's foot, is in its way. The London buses have 31 seats with one wheelchair position. Some of the regular seats are also facing the rear. The wheelchair area has three flip down seats which can be used when no wheelchair is on board. Thirty-three standees are allowed.

One wheelchair position is located on the door side. Wheelchair users are instructed to board and face the rear, positioning themselves with a padded rest behind them, a padded area on the window side (with flip down seats), and a vertical stanchion on the aisle side (Fig. 25). No other securement devices were felt to be required. A signal button on a horizontal bar in this area is used to signal the driver that the wheelchair ramp is required at the next stop.

In order for the driver to supervise the centre door area, a small video camera is mounted near the ceiling, flush to the inside wall. A monitor at the upper right of the driver station displays the area to be viewed. For the ramp to be used, the driver must first apply the parking brake, have the centre door closed, and kneel the four corners of the bus.

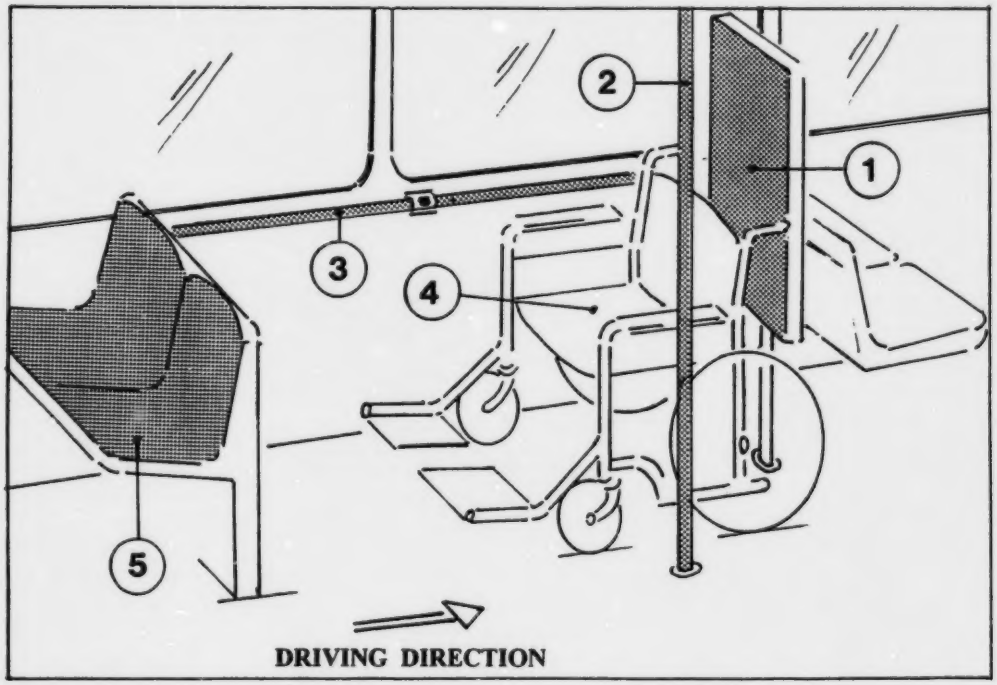
In **Sweden** "...starting points for a wheelchair securement for use in public transportation and in special transportation services for wheelchair users... " are:

- the safety and comfort of the wheelchair occupant should as far as possible be the same as that offered to passenger sitting in a regular seat in the bus
- the securement must fit common wheelchairs and no parts of it must be fixed mounted to the wheelchair
- the securement system must be easy to handle when securing the passenger and the wheelchair.

"The wheelchair securement system must keep the wheelchair safe when it is exposed to horizontal and vertical forces. When exposed to these forces, a wheelchair must not overturn, twist or shift its position. The securement system shall fit ordinary types of wheelchairs." [27]

Fig. 25 Protected position design

1. Rear-facing load bearing back & head rest
2. Aisle side vertical stanchion
3. Horizontal handrail
4. Rear-facing wheelchair position
5. Rear-facing general seats



In **France**, various accessibility solutions for urban buses have been evaluated [12,13]. One is a raised platform combined with a ramp extended from the bus, since lifts require a considerable amount of time at a stop (at least 1 - 2 minutes). Problems with this approach are (a) accessibility is not guaranteed for wheelchairs if the bus cannot adequately access the ramp (i.e. cars illegally parked etc.), (b) urban planners recognize the difficulty of integrating platforms which are raised about 53-55 cm (21"-22"), and (c) depending of the height of the sidewalk/platform, slopes of the ramp can be up to 9%, which is difficult for some wheelchair/scooter users to negotiate.

Slope

Tests carried out with wheelchairs and ramp slopes revealed the following:

- a 7.5 cm (3") height difference cannot be negotiated by the majority of wheelchair users.
- a 3.5 cm (1.5") high and 8 cm (3.2") wide gap cannot be negotiated by 20% of wheelchair users.
- most wheelchair users had no difficulties with a 10% sloped ramp and 50 cm (20") long. However an 11% slope over 70 cm (27.5") long was not attainable by 30% of wheelchair users.

On-board tests with slopes in bus floors indicated that:

- If the floor is sloped from 7-17%, the forces applied to hand holds by standing people increase by 30%
- with bus floors slopes greater than 4%, accelerations and decelerations must be considerably reduced.

Kneeling

On the subject of the kneeling bus feature, it was found that the advantages are the reduced boarding height of about 26-29 cm (10.2" -11.4") from the road, and 9-12 cm (3.5"- 4.7") from a 17 cm (6.6") high sidewalk. The time required to kneel a bus is minimal and not considered an important factor. Kneeling can be achieved in two ways, kneeling on both axles which leaves the floor horizontal, or on the right corner only. A disadvantage is expected in the attitude of drivers who believe that they do not have to stop the bus close to the curb.

Lifts & Platforms

The following indicates the problems found with lifts & platforms:

1. take too much space inside the bus,
2. require too much time for operation
3. safety can be a problem for persons waiting for deployment of the platform
4. reliability of the system
5. supervision of operation while being used.

Extended Bus Stop

In this case the sidewalk is extended outward such that the bus does not have to manoeuvre into a bay.

The advantages are (a) that this solution does not require an extra entry space, (b) good accessibility for users, and (c) less time required for bus drivers to get into boarding position. The disadvantage is that the extended bus platform can pose a safety problem for cars travelling in this lane at night. A combination of the raised platform and extended bus stop are therefore proposed, which would indicate that there is an easier integration into the infrastructure, more space for pedestrians, and a higher efficiency of the transit system due to the ease of approach by buses. A demonstration of this approach has been in place in Caen since 1992.

Test program: Cost 322
This test program was carried out by researchers in France with the participation of the Lyon transit system [11].

Within this program dynamic stress and the experimental set-up were chosen with the aim of identifying transport situations dangerous for a wheelchair user, and to demonstrate safety solutions having the minimum amount of constraints for the passenger. The tests indicated that a safe position for the wheelchair passenger had been found which is rear-facing with the back against a load bearing back and headrest, and an aisle facing stanchion/armrest. This would not require the wheelchair to be tied - down by any other equipment.

4.2 Survey of U.S. experience with wheelchair securement

In 1993, the American Public Transit Association (APTA) conducted a user survey of wheelchair securement systems and received responses from US and Canadian transit systems [1]. This survey was being conducted to determine current usage and practices regarding wheelchair securement devices. Only four-point securement systems were surveyed which comply with the ADA legislation. It is assumed that the use of "belts" in the survey refers to belts used to secure a wheelchair, not to restrain the passenger.

The results from 184 transit surveys and one manufacturer, indicate that many transit systems use the following: a wheel clamp in combination with belts (55.4%), a Q-Straint, or derivatives of both principles (40.2%). In most operations the use of belts is mandatory (80.4%).

Most operators use the wheel-clamp in combination with belts, although the use of belts is not mandatory. This seems to indicate that in practise only the clamp could be used which would not comply with ADA standards.

Only a small percentage (15.8%) of systems have had problems with missing, lost or stolen belts. One factor which was indicated points to the fact that belts do not always retract and can pose an obstacle to other passengers. Accidents were reported where other passengers tripped over loose belts (6.5%). Belts can also get soiled and become unaesthetic.

The time it takes to secure a mobility aid varies between 1 and 3 minutes, with a tendency towards the 3 minute mark. The reaction from drivers on the use of belt systems is almost evenly split 35.3% positive, and 36.4% negative. In the positive

category they "have no problems", in the negative category the most repeated comments are "belt application too time-consuming", "hard to work", "too close to passenger". The biggest drawback with Q-Straint and similar systems seems to be the storage of belts, and keeping track of having a complete set on board. Drivers sometimes "exchange belts" from vehicle to vehicle. The same applies for loose belts which are used to secure scooters.

In the past many drivers had little problems with the application of the wheel rim lock (without additional belts), but this system does not comply with current ADA standards. Additional belts on the opposite side must be used, as well as frontal tie-downs.

The reaction from wheelchair passengers for securement systems was 51.6% positive, 20.7% negative. Some surveys showed that wheelchair passenger do not like belts, but there was no indication of the reasons. Only a few accidents were reported. In one case a wheelchair passenger loosened the belts during transportation and the chair tipped over. In another case, the belts were not properly applied and the wheelchair toppled.

In summary, it seems that although it is mandatory and required by ADA to provide the four point belt securement system on-board buses, it is not always used in practice. The requirement for multiple belts also presents an ongoing problem for accessible buses.

5. EXPERIENCE WITH MOBILITY AIDS

The only major difference, aside from the seat capacity, between a lift-equipped high floor bus and a ramp-equipped low floor bus is the boarding system for wheelchair/scooter passengers. The following section summarizes the experience with both boarding systems separately and continues with the other issues which do not differ as much from each other, regardless of which type of bus is used. Appendices A and B provide a photographic illustration of a complete experience, from boarding to securement, for wheelchair and scooter users.

5.1 Boarding

Ramp

Low floor, ramp-equipped buses make access for all passengers easier, including those using a wheelchair/scooter. The introduction of these buses has been received with great enthusiasm by the population with mobility impairments, as well as by the general public. Not kneeled, the height difference between the sidewalk/station platform at 15 cm (6") and the bus floor is around 22 cm (8.6"). When kneeled, the difference is about 12 cm (4.6"). Not having to negotiate steps decreases boarding and alighting times only marginally but reduces the probability of accidents.

For passengers using a wheelchair/scooter, a ramp is deployed by the driver and swings out, extending onto the sidewalk/platform about 1.02 m (40"). A clear platform area of 2.23 m (88") long and at least 90 cm (36") wide is required at the stop/station for loading/unloading a wheelchair passenger. The length of 2.23 m (88") includes the ramp of 1.02 m (40") plus the length of the wheelchair of 1.22 m (48"). The ramp can be operated manually by the driver without interrupting or delaying route service.

When the bus is kneeled and the ramp is resting on a curb, the inclination of the ramp is very easy to negotiate, because the inclination is about 5 degrees or less, depending on the height of the curb. The inclination of the ramp when deployed to the road, rather than to a curb, is rather steep (about 13 degrees) and can create a safety problem for scooters and other wheelchairs.
Drivers prefer the ramp over the lift, because of its simplicity of operation. The ramp is of light weight design, and more forgiving to flex than the more rigid lift platform. It can therefore adapt more easily to the irregularities of the road/curb. Another advantage of the ramp is that it is often used by other mobility impaired passengers, e.g. those using walkers, canes and crutches, etc.

Nevertheless the ramp is not without inconveniences. One is the fact that the driver must alert waiting passengers outside to make room for the deployment, and the other is that the storage area inside the bus must be kept free of dirt and silt, especially in the winter in order to avoid the ramp from protruding above the floor, its edges possibly becoming a dangerous obstacle.

Lift

Lift-equipped buses represent some problems for transit systems in Vancouver, Champaign-Urbana and Ann Arbor. At the time of implementation several years ago, they probably represented the best possible concept on the market, but with the introduction of low floor buses and ramps this concept seems to have several disadvantages.

Lifts are technically complex products and if they break down, service route schedules are interrupted and delayed. In the case of malfunctioning and the driver being unable to operate the rather complex manual back-up system, a supervisor must be dispatched or a bus replaced, resulting in schedule delays, inconvenience for passengers and increased costs for the transit system.

A clear platform area of 2.80 m (9') in length is required at the stop to load/unload a wheelchair passenger. While the lift is in use, no other passenger can board the bus until the full lift cycle is completed, which requires approximately 12 operations (move out from storage, lower platform, board wheelchair, apply front and rear barriers, lift platform, level front barrier, exit wheelchair, fold barriers, extend platform outwards, lower platform, move platform into storage). One full boarding cycle can take about two minutes or more.

For standing mobility impaired passengers, (e.g. people using crutches, canes, walkers, the elderly, etc.), two handrails are attached to the platform that they can hold on to for stability. When the lift is used for standing passengers, they must be cautioned about the limited vertical clearance of 1.50 m (59") between the platform and the door opening. Boarding and alighting for elderly passengers via stairs creates longer dwell times and increases the possibility of accidents.

For both ramp and lift equipped buses, the driver must approach the bus parallel to the curb if the use of either boarding technology is required. When not parked parallel, the platform could contact the curb surface on one corner only and be torsioned, thus damaging the hinge, and creating an unstable approach for the wheelchair/scooter passenger.

5.2 Fare payment

The fare payment box is usually located near the driver's station, and the height to insert coins can vary from 1.02 m - 1.17 m (40"- 46"), depending on the design of the box and whether it is mounted on a pedestal or not. For a person in a wheelchair 1.17 m (46") is too high to visually verify correct insertion. For elderly and disabled persons the handling of coins can create a problem due to finger agility problems, although most elderly and disabled passengers who travel frequently have a pass. If for any reason the disabled passenger does not pay, the driver often turns a blind eye. For passengers in wheelchairs or scooters the fare box location sometimes creates a problem, because they approach the fare box too close and realize, too late, that they have not enough room left to turn 90 degrees into the bus. In particular, scooters with baskets mounted on the front can have difficulty turning.

5.3 Proceeding to the seat

The location for wheelchair/scooter and for priority seating is toward the centre of the bus. In high floor buses the wheelchair/scooter passenger must move past vertical stanchions and side-facing seats on each side with passenger's feet extending into the centre aisle. In low floor buses wheelchair/scooter users must pass between front wheel wells (width 89 cm - 35"). Neither case presents a problem as long as the area is kept clear of standing passengers.

5.4 Preparation of the securement

In an ideal scenario the wheelchair passenger arrives and all seats are flipped up. The worst scenario is that all flip seats are down and must be lifted. A lever under the seat must be pulled to move the seat into the vertical position. For the transverse seat this means lifting a double seat. Pulling the levers and lifting the seats requires substantial strength, especially when working from a seated position in a wheelchair or scooter, something most wheelchair passengers cannot do. In addition, it requires the wheelchair/scooter user to manoeuvre close to all seats first in order to flip them and to get into the securement position. All this adds time to the boarding cycle and may require asking other passengers to vacate their seats if the they occupy the priority seats. This is unpleasant for the passenger in the wheelchair as well as for other passengers.

5.5 Manoeuvring into securement position

If the wheelchair/scooter passenger boards the bus facing the rear, he/she must turn the chair 180 degrees in order to back against the securement and face forward. This turn takes place in the centre aisle of the main traffic corridor, requires a circle of approximately 1.50 m (60") and can create several problems. Because this section is also designated as a priority seating area it can be occupied by other mobility impaired passengers using crutches, canes etc. or elderly persons. If a wheelchair/scooter turns, some of the seated passengers may be asked to vacate their seats to make room for the wheelchair, which creates an unpleasant situation for the seated person and for the wheelchair passenger. Most of the time the turn cannot be made in one movement and requires several back and forward movements, adding time to the operation and stress for the passenger. Also, backing up against the securement and clearing the floor anchor on the inboard side can be a problem for scooters. If this anchor is not cleared, the scooter must be lifted or the belt cannot be used.

5.6 Securement and passenger restraint

Securements in use in Canada consist of mainly two types: the wheel-rim clamp, and the angled stop. Both immobilize the wheelchair with belts and hooks which are attached from rear anchor points to the rear or front of the wheelchair frame. These systems immobilize the wheelchair against forces during regular transit operation, including severe braking and cornering. No accidents have been reported which would indicate that these systems are adequate.

Wheel-rim lock:
The wheel rim lock is an automatic clamp mounted about 28 cm (11") above bus floor level on one side of a double seat bench. It locks one large rear wheel of a wheelchair at its centre when the wheel is backed in against a plate, thus activating the clamp's mechanism. Wheelchair passengers must back-in very precisely since the opening is only 89 mm. (3.5") wide and provides no "guide". This is especially difficult when using electric converted chairs with wide 70 mm (2.75") tires. Also, to avoid a seat post from the side facing seats, precise manoeuvring is required. In addition to the wheel lock, a belt on the opposite side must be pulled out and attached to the chair. To unlock, one must reach behind and push a level at the height of the lock. For scooters, the wheel-rim lock is not suitable since the small scooter wheels do not reach the clamp. Instead, two retractable rear belts, one on each side, are mounted to the seat bench base and a separate belt (stored behind the driver's seat) is connected over the foot rest area of the scooter. Technical problems with the wheel-rim lock can include a poor working mechanism, damaged wheelchair rims, loose fit of the wheel which allows side play, and belts which do not always retract.

Angled Securement:
The angled stop is a stainless steel box mounted under a transverse seat bench at about 28 cm (11") above bus floor level. A multiple position track is mounted on top of the box, with two tie-downs belts which can be positioned at any point of the track to adapt to different wheelchair/scooter widths. The front of the box is angled towards the centre aisle to help wheelchair passengers back in easier and clear the side seat post. At the end of the tie-down belts are hooks which must be connected to the wheelchair scooter, after which the belts should be tensioned. Problems with the angled stop can include hooks which do not fit a scooter frame or any other attachment points of the scooter. Floor anchor points for the transverse frontal scooter belt are often filled with dirt and make a positive connection difficult.

The main problem with these systems was found in the operation. Both require the help of a companion/assistant to deploy hooks and belts and apply tension to the belts. The great majority of wheelchair/scooter users cannot reach behind and down to retrieve belts and hooks, or connect them to floor anchors. Backing up with one large rear wheel into the wheel-clamp requires the passenger to turn his/her head, look behind, verify the position and engage the wheel and can be very difficult for some people.

When in need, the driver is often expected to help the wheelchair passenger, which is not his/her responsibility. The principle of the two-for-one fare has been introduced in several transit systems in Canada in order to relieve the driver from assisting. The companion rides free but is responsible for all tasks required, from manoeuvring the passenger into position, deploying the securement and lap belts if required, and for detaching and alighting the passenger.

In some transit systems the front belt used for the scooter is stored over the wheel well and must be requested from the driver, in other operations the belt is attached with one end permanently fitted to the floor and the other hooked under a seat. Both solutions are unsatisfactory. The first requires the driver to be responsible for the return of the belt to the box, the second creates dirty and soiled belts. Another problem was found with belts which do not retract fully and hang loose or lay on the floor, thus creating hazards for other passengers.

The other major problem is to find suitable strong points on scooters to connect the rear belts. In many cases armrests, seat column or plastic covers are used which can get damaged and do not provide appropriate strong anchor points. The same is true when the front belt is wrapped around the steering column, which is often detachable. Neither the scooter user, nor the companion know where and how to attach the belts.

5.7 Stop request

There are several methods used for the wheelchair passenger to request a stop - a vertical pull cord, a sensitive touch strip, or a push button. All are mounted within easy reach for the passenger and, when activated, display a lit "Stop Request" sign at the front of the bus. All methods were found easy to use. It was nevertheless suggested that the control activated by the wheelchair passenger provide a different signal to the driver so that he/she can prepare for alighting and the deployment of the lift or ramp.

5.8 Alighting

The general public exits through the mid door, the wheelchair/scooter passenger through the front door. In case of a lift, the driver must alert waiting passengers outside that the lift will be deployed, although there is a flashing light signal on the outside of the bus near the door as well as an audio signal. The wheelchair passenger must wait until the driver has the platform moved from the stowed into the loading position, which can only be done when the bus has come to a complete standstill, the front doors are opened and locked, the four flashers are switched on, and the main brake is set. The wheelchair passenger can move onto the platform with the curbside barrier up. The platform is then moved horizontally out over the curb and down. With the curbside barrier down, the wheelchair can move off the platform, which is then retracted into its stowed position. Once this cycle is complete, all other passengers can board.

In case of the ramp, the driver must alert passengers waiting outside that he will move the ramp. Once deployed, the wheelchair /scooter passenger can exit and all waiting passengers board over the ramp. Although the stepless entrance does not have a significant influence on reducing dwell times for the general public it nevertheless reduces the probability of accidents. In addition it provides convenience, especially in the winter when the bus cannot stop close to the curb and there is a larger gap between bus and curb. It was reported that some passengers wearing a hearing aid felt interference with the audio signal which indicated the deployment of the ramp or lift.

6. SAFETY STANDARDS

6.1 Comparison of standards

In Canada there are no regulations or standards for wheelchair securement systems in large buses. CSA Z604 and Z605 are standards for the design of mobility aids and their securement to be used in motor vehicles of less than 6500 kg GVW, but do not specify other aspects of accessibility for transit buses. Three standards that are relevant to this study are: D409, ADA, and ISO. Table 7 shows a comparison of these standards.

CAN/CSA D409-92 is the Canadian Standard for Motor Vehicles for the Transportation of Persons with Physical Disabilities [7]. Although its application has been limited to vehicles with GVWR of less than 10 000 kg, it nevertheless provides a basis of comparison to the more familiar accessible paratransit vehicles.

The Americans with Disabilities Act (ADA) defines a large number of requirements for accommodating and integrating persons with disabilities into society. Its relevance for this study stems from the stringently defined requirements for accessible public transportation vehicles, including transit buses.
" Securement systems on vehicles with GVWRs of 30,000 pounds or above, and their attachments to such vehicles, shall restrain a force in the forward longitudinal direction of up to 2,000 pounds per securement leg or clamping mechanism and a minimum of 4,000 pounds for each mobility aid. Securement systems on vehicles with GVWRs of up to 30,000 pounds, and their attachments to such vehicles, shall restrain a force in the forward longitudinal direction of up to 2,500 pounds per securement leg or clamping mechanism and a minimum of 5,000 pounds for each mobility aid."

The ADA therefore sets a standard in the U.S. which requires that the wheelchair frame is attached with a relatively high performance specification in the area of 20 g. In contrast, the European countries pursue another approach which provides only a compartment with padded panels and a rear facing wheelchair passenger but no other securement components.

The ISO working document 10542, and ISO document 7176/19 were also reviewed and revealed no definition of a "Motor Vehicle", in terms of weight or size [20,21]. They specify securement systems, occupant restraints and wheelchair attachment points as follows:

- *"wheelchair tie-down: A device or system securing a wheelchair in place in a motor vehicle during normal travel as well as during a collision.*
- *four point tie-down: A wheelchair tie-down system that fastens to the wheelchair at four separate points on the frame and anchors to the vehicle at four different locations. The typical four-point tie-down system uses four tie-down belts or straps.*
- *automatic tie-down: A wheelchair tie-down device that locks the wheelchair in place automatically when the wheelchair is rolled into position.*

- *occupant restraint: A system or device for restraining the occupant in a motor vehicle to prevent or minimize contact with the vehicle interior components and prevent ejection during a crash.*
- *a wheelchair designed to interface with a Wheelchair Tie-down and Occupant Restraint System (WTORS) system that complies with this standard shall have not less than four attachment points, two at the front and two at the rear of the wheelchair."*

Table 7
Comparison of standards defining vehicle requirements for the transport of persons with disabilities

Components	CAN/CSA D 409-92	ADA	ISO documents 10542 & 7176/19
1. Clearance envelope	floor space of 27 x 44"; 44" along the long axis of the vehicle	30" wide x 30" high x 48" long; toe clearance under seat: 6" deep x 9" high	660 mm x 1270 mm (26" x 50")
2.Ramp slopes	1:4 general , and in kneeling mode	1:4 when height difference is up to 3" 1:6, when difference up to 6" 1:8, when difference up to 9" 1:12, when difference. greater than 9"	Not specified
3. Number of wheelchair securement positions	conforming to CSA Z605 and 604	1 for buses up to 22' in length; 2 for buses over 22'	Not specified
4. Passengers position	forward or rearward, CSA Z605	forward; rearward: with padded barrier	forward: with head restraint only if back restraint is provided in vehicle rearward: head and back restraint required
5. Type of wheelchair securement	4 point anchorage: 2 in front and 2 at rear	4 points	4 points - 2 in front and 2 at rear; attachments independent of passenger restraint but could use same floor anchor points.
6. Type of passenger restraint	lap and torso belt	seat belt and shoulder harness, separate from wheelchair securement, for each wheelchair position	pelvic restraint or pelvic and torso restraint independent of wheelchair securement but can use same floor anchor points
7. Performance of wheelchair securement	for vehicles with GVWR < 10 t forward and rearward static loading: 1600 kg (3520 lbs) with mobility aid of 80 kg (176 lbs)	for vehicle above 30 000 lbs GVWR securement up to 2000 lbs per securement leg or clamp mechanism, min of 4000 lbs for each mobility aid for vehicles less than 30 000 lbs: 2500 lbs/ leg and min. of 5000 lbs per mobility aid	in accordance with FMVSS 209 < 3,5 t at 50 km/h - 20 g 3,5 t - 6.5 t at 34 km/h:20 g >6,5 t at 34 km/h 10 g
8. Air bags	N.A.	N. A.	if used , only in conjunction with wheelchair securement and passenger restraint

Table 7 continued

Components	CAN/CSA	ADA	ISO
9. Performance of passenger restraint	CSA-Z605, seat belt assembly components to meet CMVSS 209 and 210; if wheelchair securement and passenger restraint share common anchorage points, loads as in # 6 and 8 should be met simultaneously	according to 571	
10. Degree of assistance required for engaging and disengaging	by operator: manual engagement and disengagement of each point	automatic or easily attached by person familiar with system or by wheelchair passenger when capable	attachment and release without use of tools
11.Special features for payment	Not specified	if fare box available, position not to obstruct wheelchair path	Not specified
12. Stop request	Not specified	for buses over 22' length: auditory and visual indication; control adjacent to wheelchair passenger's place	Not specified
13. Emergency doors	32"wide x 45" high	Not applicable	Not applicable
14. Other emergency features	if emergency exit is provided in roof, it shall comply with CMVSS 217 and operated from exterior of vehicle	Not specified	Not specified

Note: a full size urban bus weighs typically more than 30.000 lbs, or 14 t

In determining the appropriate "level of safety" to be provided to persons with disabilities, from a policy perspective, it would be valuable to determine the level of safety currently provided to other passengers, including standees and seated seniors. Unfortunately, we have not been able to identify any research that quantifies the deceleration forces that would be unsafe to standees in order to compare them with actual experience. Groups of disabled persons often express the desire to be treated equivalently to other passengers, including the levels of safety provided.

6.2 Other considerations

CUTA has explored the desirability of developing comprehensive standards for accessible full size buses. Although a consensus has not yet emerged to develop such standards, a number of considerations have appeared in light of the previous comparison of standards. They are briefly described in the following section.

Mobility Aid Passenger Seating
If, as research and general industry practice indicate, the deceleration forces in a full size transit bus are considerably less than in lighter weight vehicles, e.g. vans and passenger vehicle, then the possibility of sideways facing or angled positioning should not be excluded.

Floor Space
With an increasing number of scooter users becoming part of transit users and their increasing dimensions with add-on baskets etc., the minimum floor space of 0.71 m x 1.22 m (28" x 48") needs to be verified. This would also increase the manoeuvring space to get in and out of the securement position.

Manoeuvring Space:
In addition it should be noted that a minimum of 0.91 m (36") diagonal is necessary to turn a mobility aid 90 degrees. If wheelchairs and scooters are to pass along an aisle, the width of the aisle must be a minimum of 0.73 m (29 ").

Occupant Restraint System
It should be at the discretion of the mobility aid user to use a restraint system. A personal restraint should be consistent with the requirements and forces experienced on a large transit bus.

Anchorage points
Anchorage points should be according to restraint system requirement for full size transit buses.

Gradient
The suggested gradient of 1:4 may be too steep, especially when the ramp is torsioned and a top-heavy scooter is using the ramp. Tipping can occur under these
circumstances. A gradient of 1:10 is recommended.

Other
When the ramp is deployed, an audio and visual warning signal should be displayed to passengers and people walking by the loading area.

7. CHOICES

Presently transit systems in Canada have a number of key issues to decide upon in accommodating disabled persons.

1. Accessible door:
    - Front (option on all New Flyer low floor buses in service)
    - Middle/centre (initial design for first Nova Bus low floor buses to be delivered in 1995)

2. Number of wheelchair positions:
    - 1
    - 2

3. Location of wheelchair positions:
    - Behind front wheel wells (common to date)
    - Other (likely in new Nova Bus low floor buses)

4. Number of flip-up seats per wheelchair location
    - 4 (2 forward and 2 lateral)
    - 5 (2 forward and 3 lateral)

5. Wheelchair securement:
    - Wheel-rim lock + 2 rear belts, 1 front belt for scooter
    - Angled stop with 2 rear belts, 1 front belt for scooter (with lap belt if required)
    - Independent Locking System (ILS), (wheelchair must be outfitted with D rings)
    - 4 belt systems, 2 front and 2 rear belts, tie-down for battery operated wheelchair

6. Passenger restraint:
    - Lap belt with wheel-rim lock and angled stop
    - Passenger has own belt on wheelchair
    - 3 point belts system (lap and shoulder harness)

7. Fare payment:
    - Fare box
    - Pass
    - 2 for 1 fare for companions of disabled passengers

8. Stop request controls:
    - Push button
    - Touch strip
    - Bell cord

8. RECOMMENDATIONS

With the rapidly increasing move towards low floor buses in transit systems in Canada, several aspects of accessibility must be solved urgently, otherwise transit systems will be faced with costly retrofitting in the years to come.

All accessibility factors in a bus are interwoven, e.g. the service door position has a bearing on the location of the wheelchair position; the securement system position on the fare policy; the seat capacity on the securement system, etc. None of the aspects can be considered in an isolated way, but must be viewed in terms of the constraints imposed on other elements.

Based on the investigation the following recommendations are considered important in order to make access to transit buses more efficient for the operators and more convenient for wheelchair /scooter passengers:

1.Passenger safety

- determine level of safety for all bus passengers, including standees and those using mobility aids, and develop standards (should an equivalent or superior level of safety be provided to persons with disabilities?)
- investigate reducing or relocating manoeuvring space for wheelchair/scooter passengers without interfering with main passenger flow within a bus (should the 0.71 m x 1.22 m, 28" x 48" envelope be increased?)
- explore German and UK experience with protected position designs

2. Technologies

- investigate forward, sideways or angled facing of wheelchair/scooter passengers in order to provide acceptable safety levels for wheelchair/scooter passengers
- investigate protected position designs for accommodating mobility aids in Canadian context
- make securement adaptable to all commonly used wheelchairs and scooters
- investigate use of centre door for wheelchair/scooter access
- develop differentiated signal for stop request by wheelchair user

3. Operation

- reduce operation of hooks and belts for securement
- reduce driver involvement for securement or physical assistance
- reduce conflict between needs of persons with mobility aids and other "priority" persons

4. Policy

- determine the appropriate level of customer service
- investigate self-service fare payment, eg. honour system, smart card etc.
- investigate capacity considerations
- investigate two-for-one companion fare policies

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APPENDICES

A Photographic log of wheelchair boarding and positioning

B Photographic log of scooter boarding and positioning

C Findings from German research on wheelchair-accessible buses

D CUTA Forum article: "Low floor takes to the streets of London"

APPENDIX A

Photographic log of wheelchair boarding and positioning

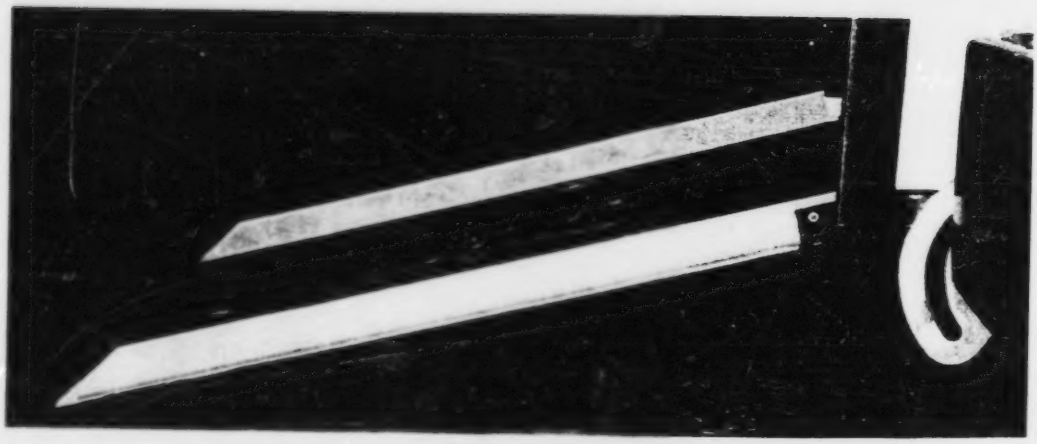

Fig. 1 Ramp at front door of low floor bus - New Flyer

Fig. 2 Light for kneeling and ramp operation

Fig. 3 Manual deployment of ramp

Fig. 4 Person in manual wheelchair boarding over ramp

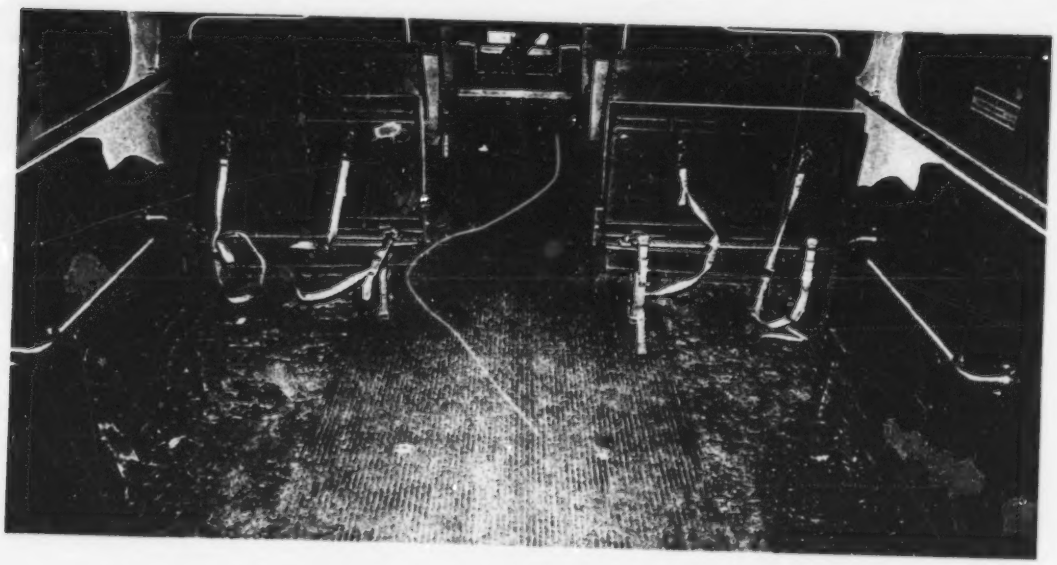

Fig. 5 Two wheelchair positions with angled securement, priority seats in "up" position

Fig.6 Designated area for priority seating

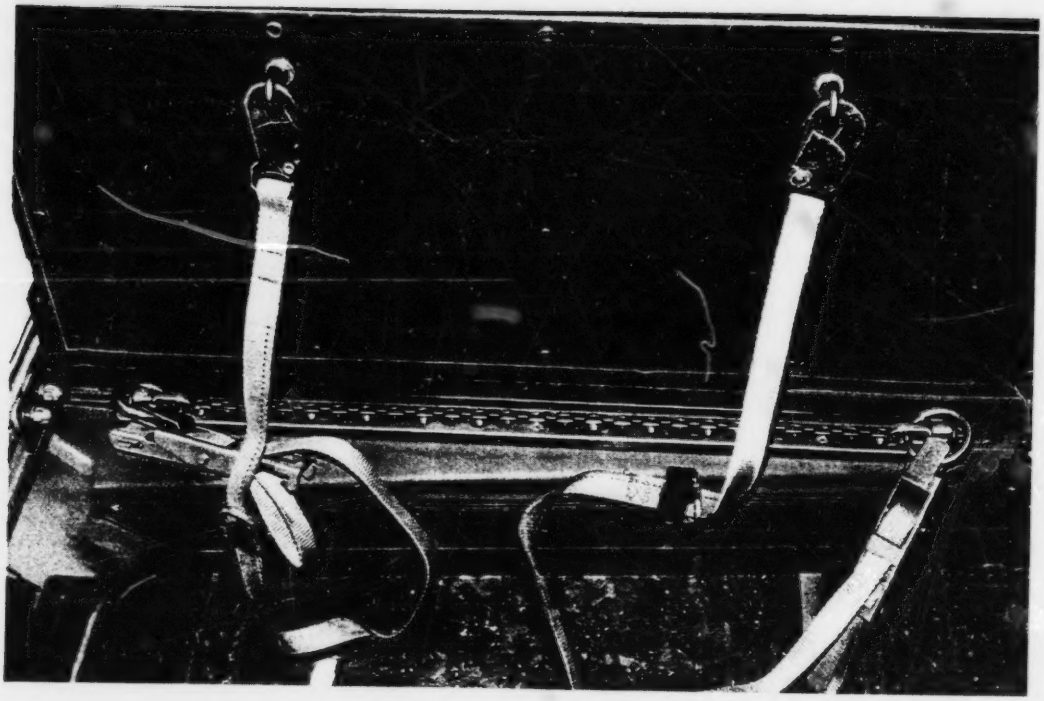

Fig. 7 Angled securement with rear tie-down belts, ratchet and hooks

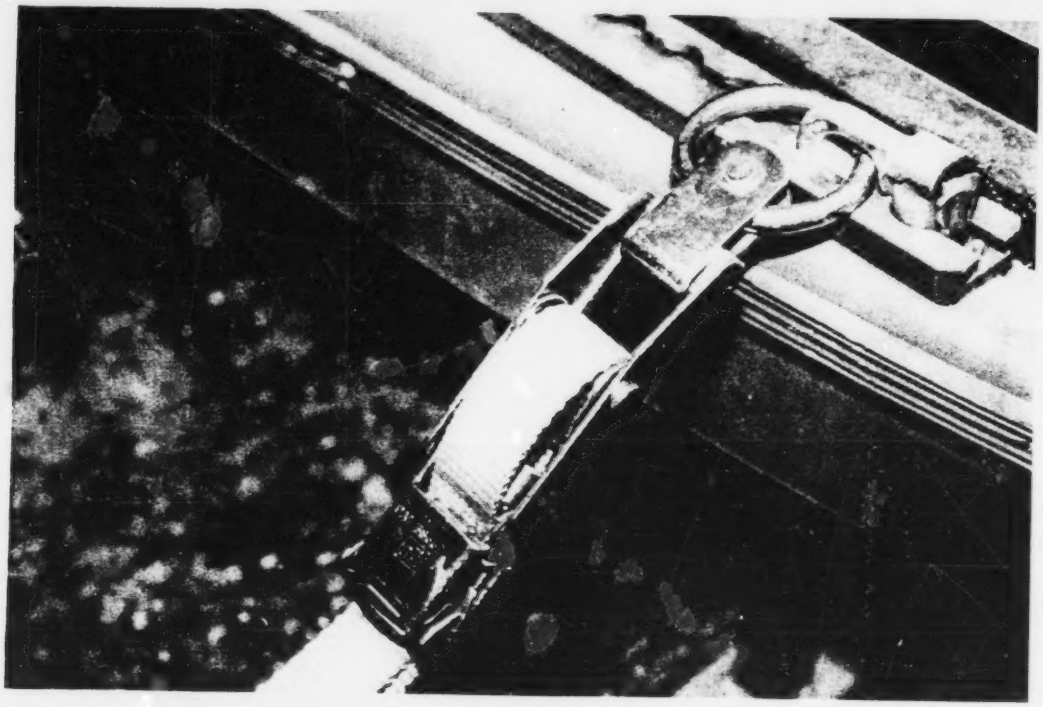

Fig. 8 Multi-position track with ratchet to tension belts

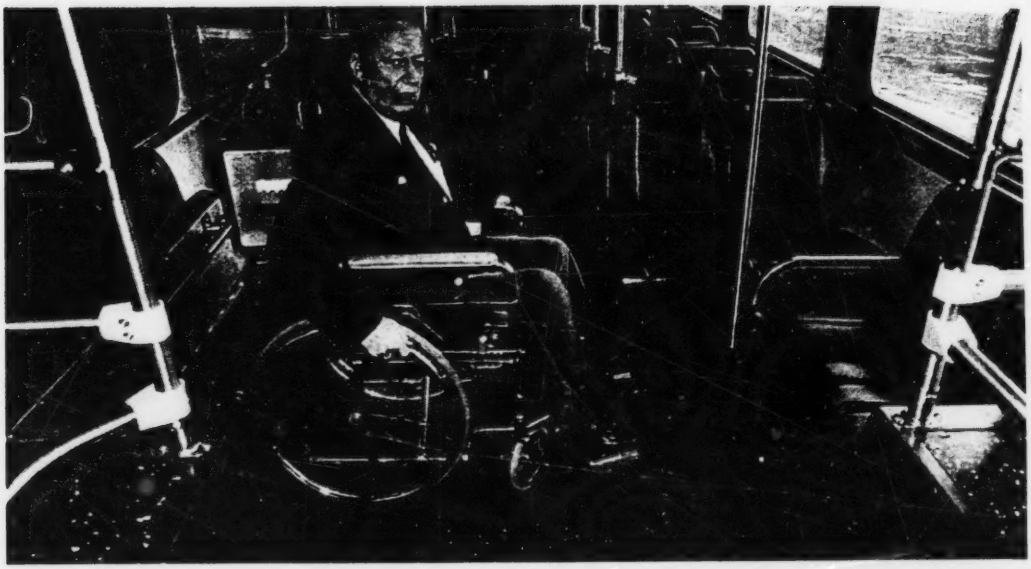

Fig.9 Person in manual wheelchair manoeuvring into position behind front wheel well - 180 turn required

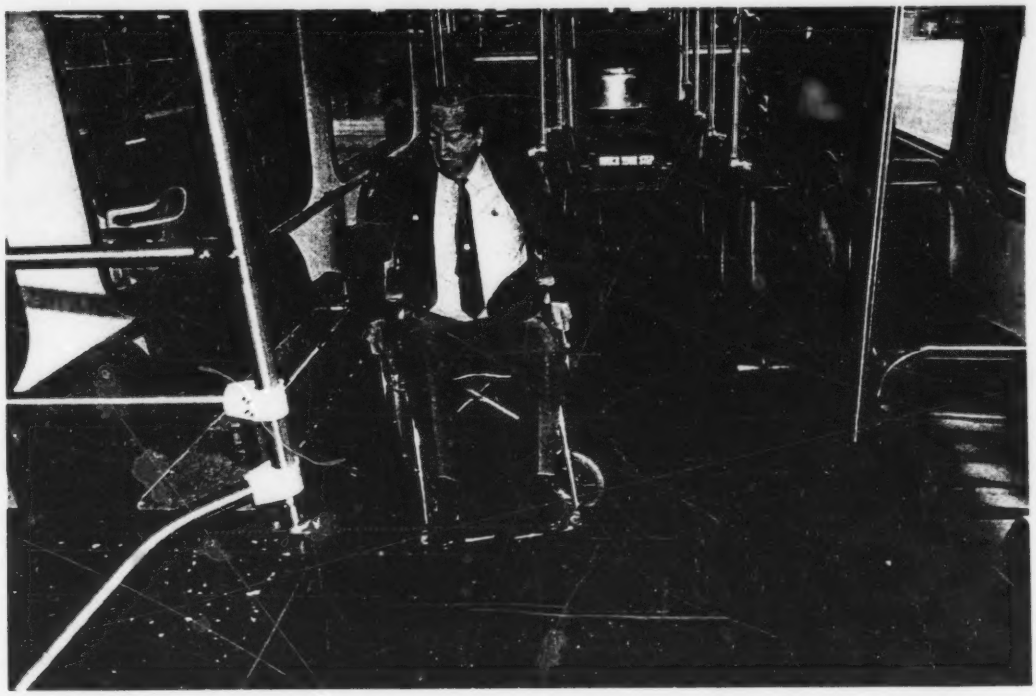

Fig. 10 Backing against securement system

Fig. 11 A person other than the wheelchair occupant must apply/disconnect rear tie-down belts

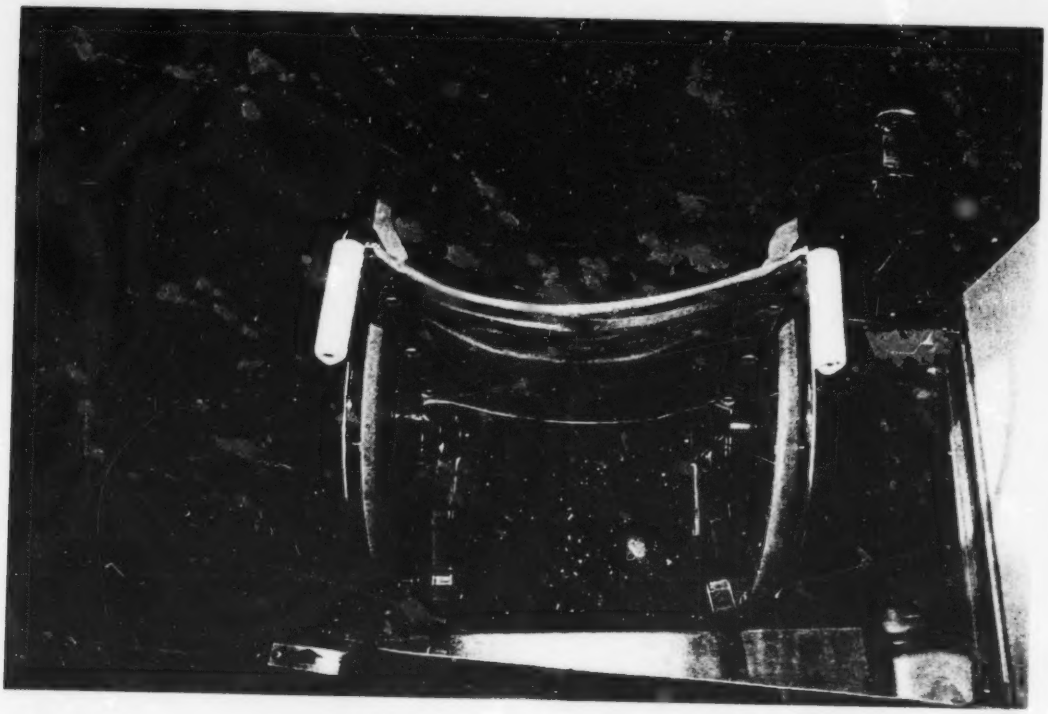

Fig. 12 Wheelchair in secured position with two rear belts

Fig. 13 Use of occupant lap belt is optional

Fig. 14 Wheelchair position with Wheel-rim lock securement; 5 seats must be flipped up; stop request is located on handrail

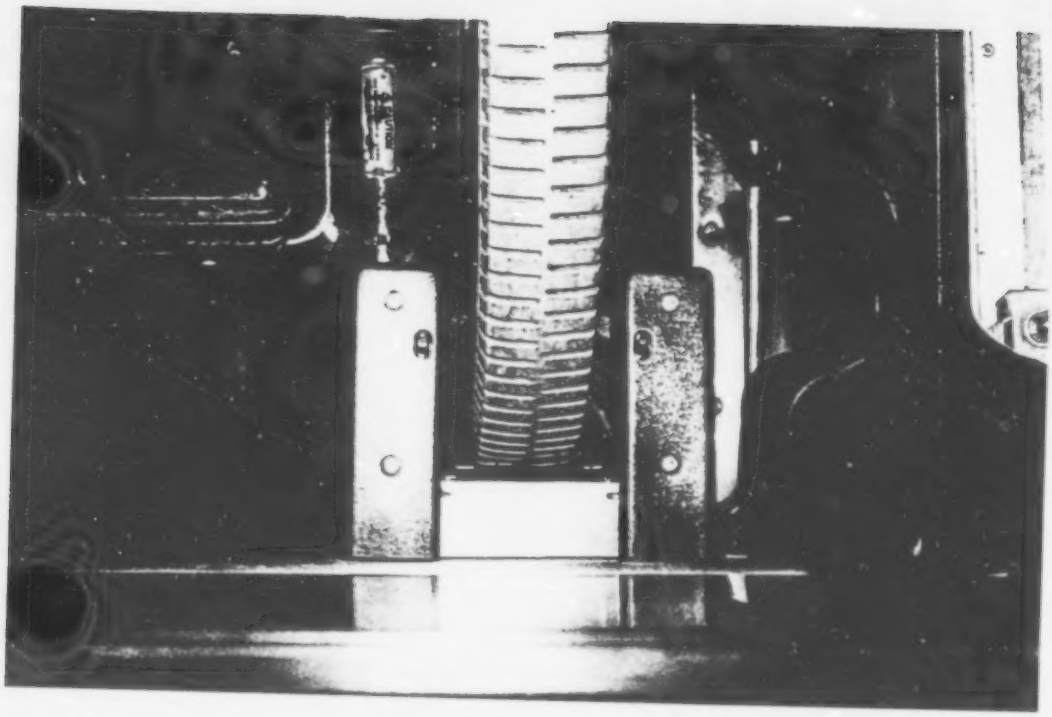

Fig. 15 Wheel-rim lock securement on wall side - tight fit for wide tires

Fig. 16 Retractable belt to secure wheelchair on opposite side (aisle side); optional lap belt for occupant

Fig. 17 Lit stop display at front of bus

APPENDIX B

Photographic log of scooter boarding and positioning

Fig. 1 Deployed ramp with colour markings on edges; handrails on doors for elderly persons and general public

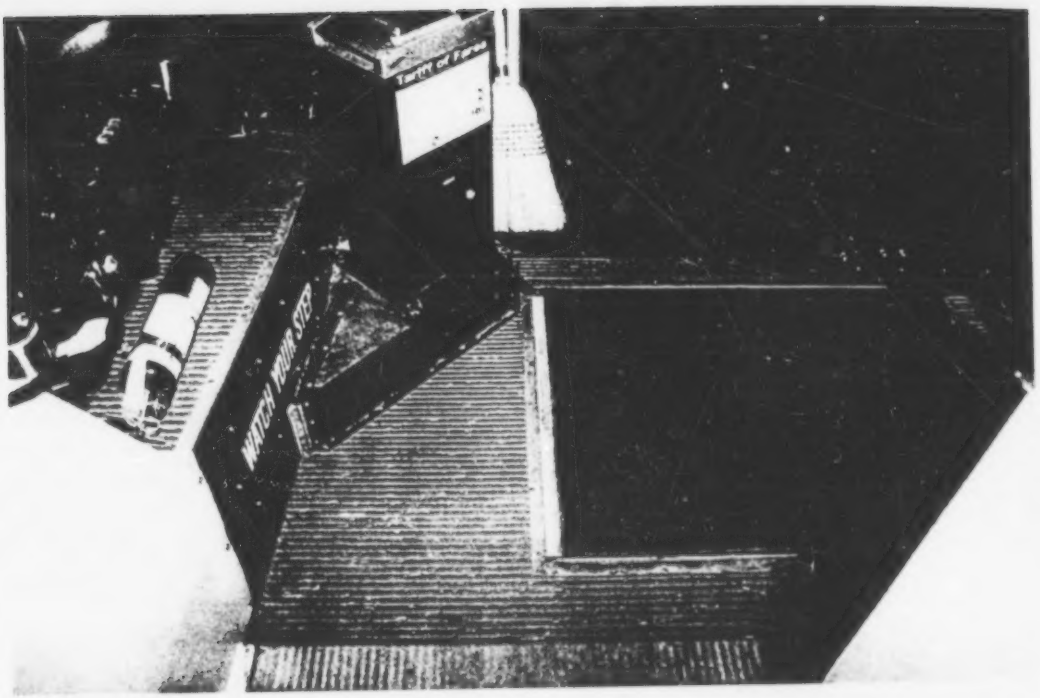

Fig. 2 Fare payment box on pedestal

Fig. 3 Person in scooter boarding over ramp at front door

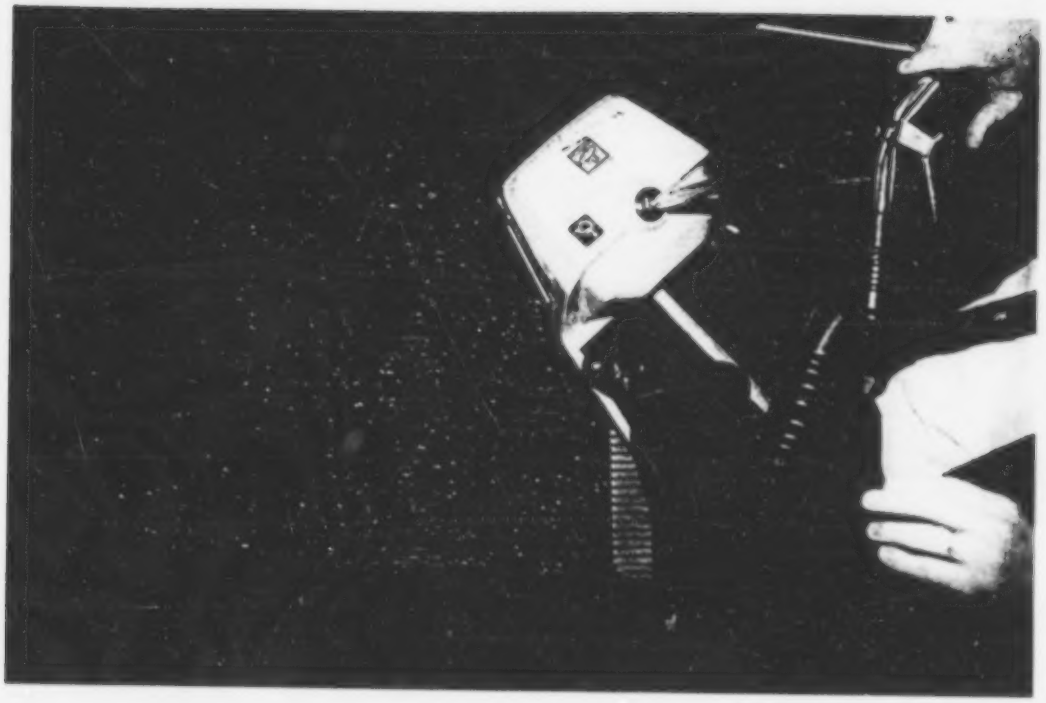

Fig. 4 Person in scooter facing tight turn (90 degrees), from fare payment position into aisle

Fig. 5 Person in scooter must turn 180 degrees in aisle, which requires several back up and forward manoeuvres

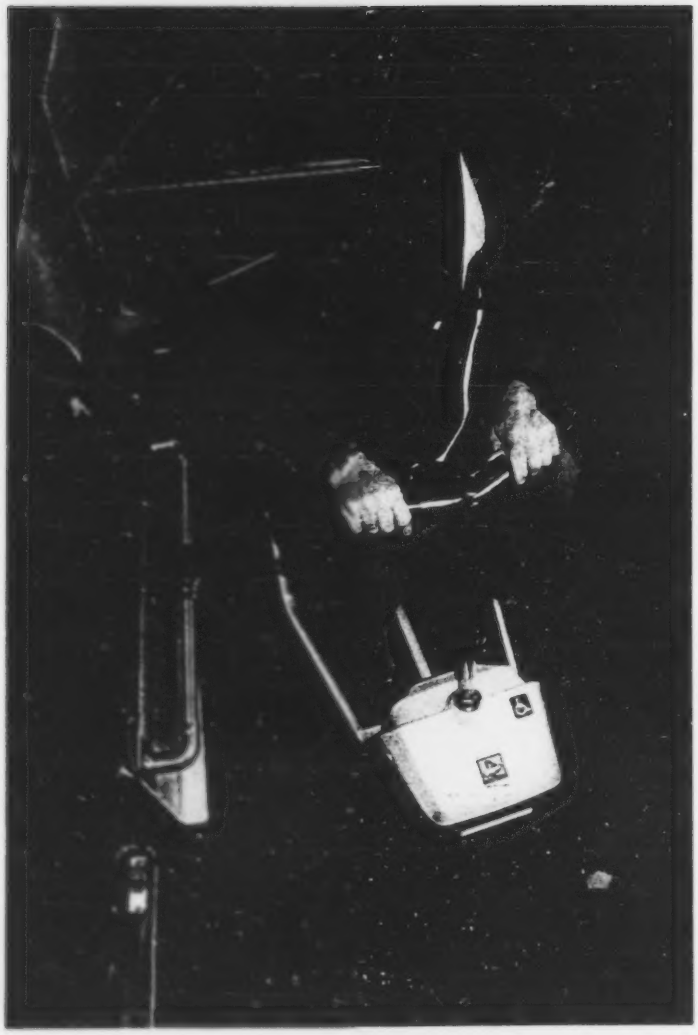

Fig. 6 Scooter backs up into securement and faces forward in travelling position

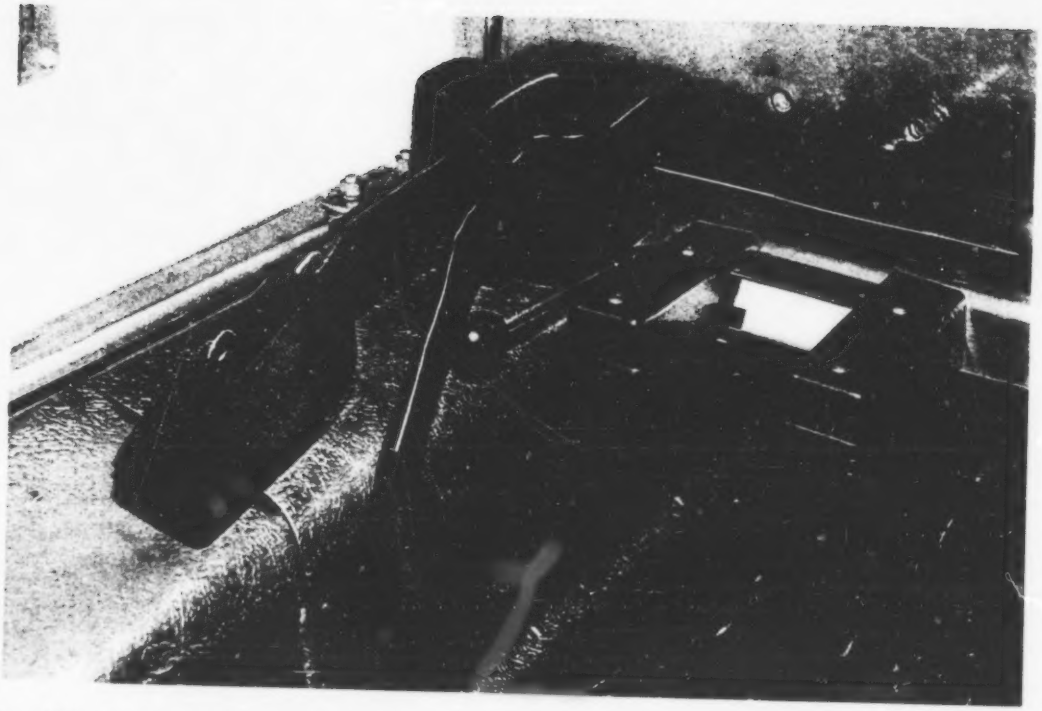

Fig. 7 Wheel-rim securement cannot be used for scooter, instead two retractable rear belts - one on each side - must be attached to the rear of the scooter

Fig. 8 A front belt is required to secure a scooter

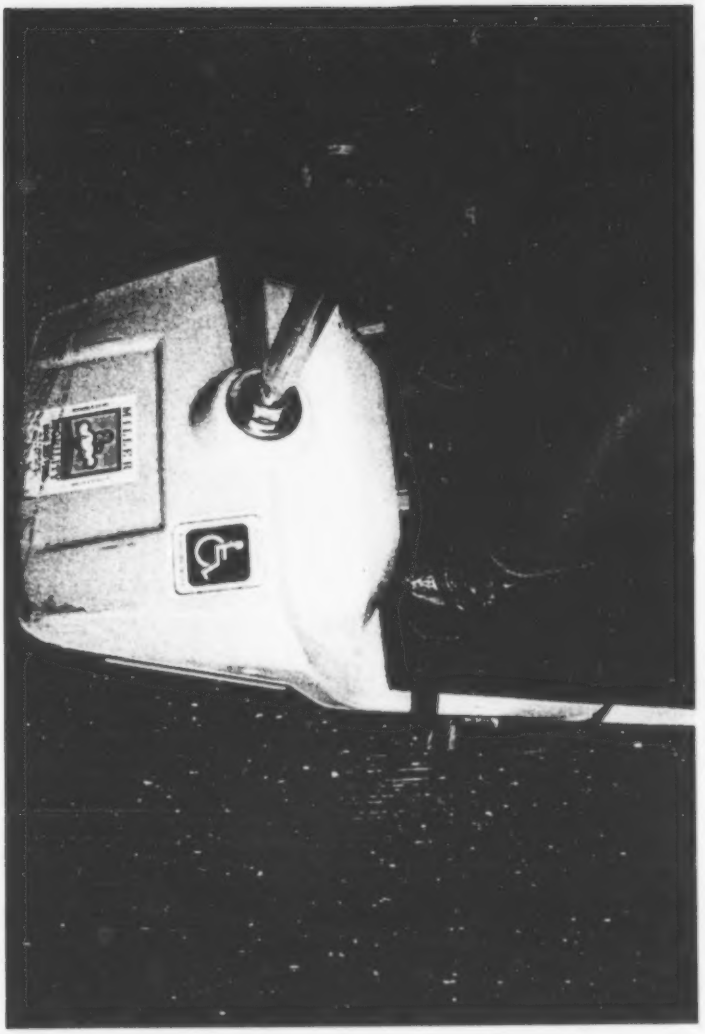

Fig. 9 The deployment of the front belt may require that the occupant's legs be lifted

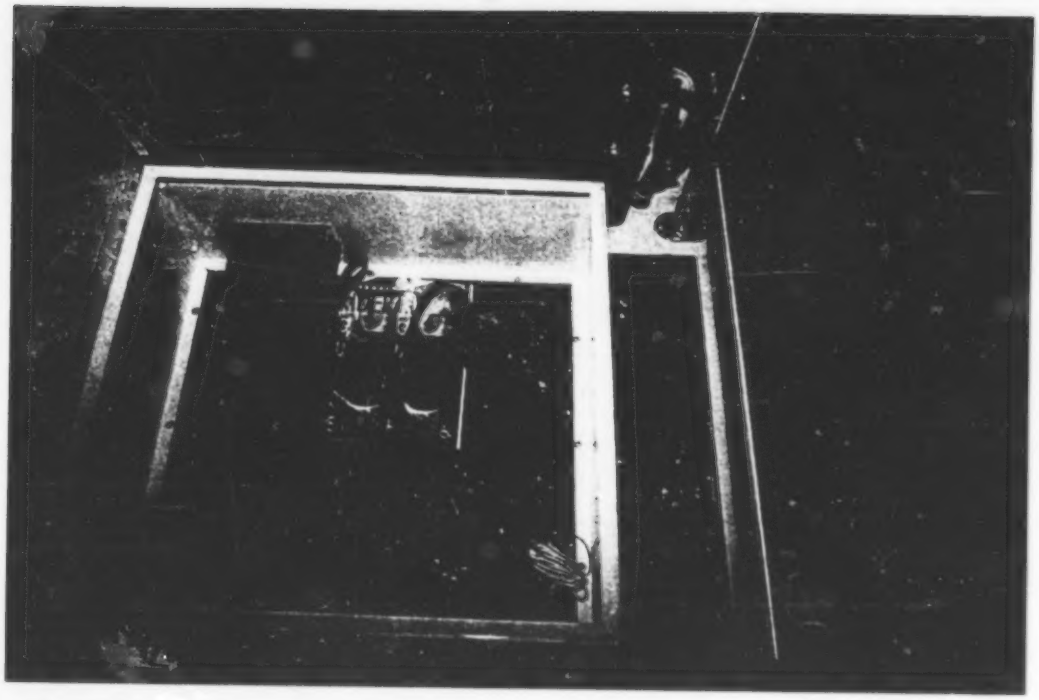

Fig. 10 Some transit systems store front belts for scooter in box on wheel well

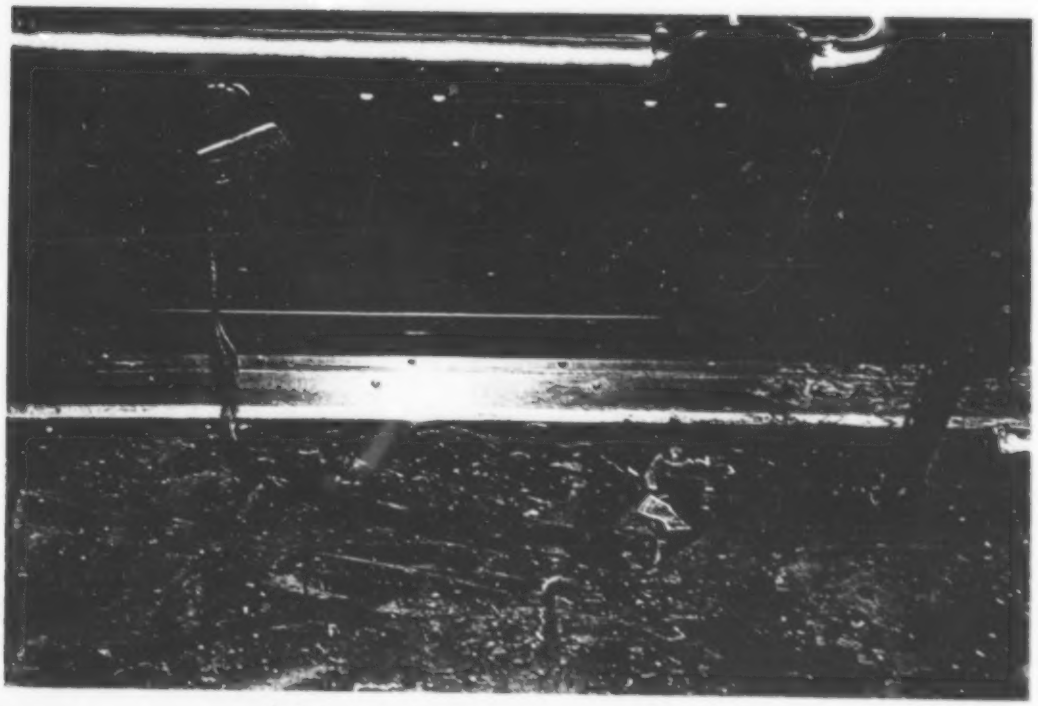

Fig. 11 Other transit systems have one end of front belt permanently connected to floor

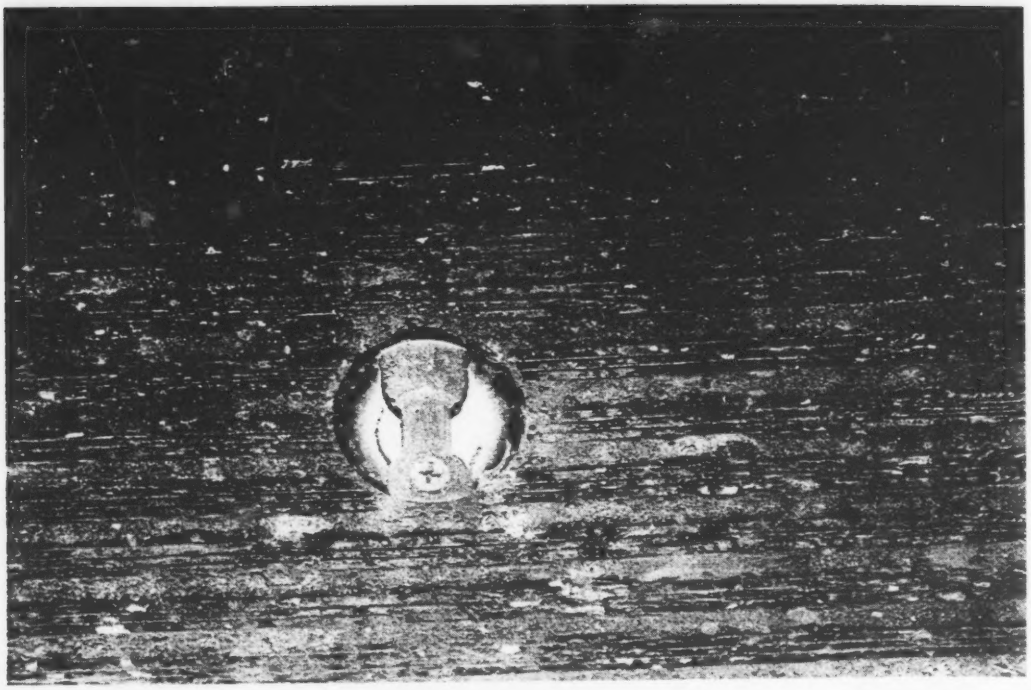

Fig. 12 Receptacle for front belt - mounted above floor

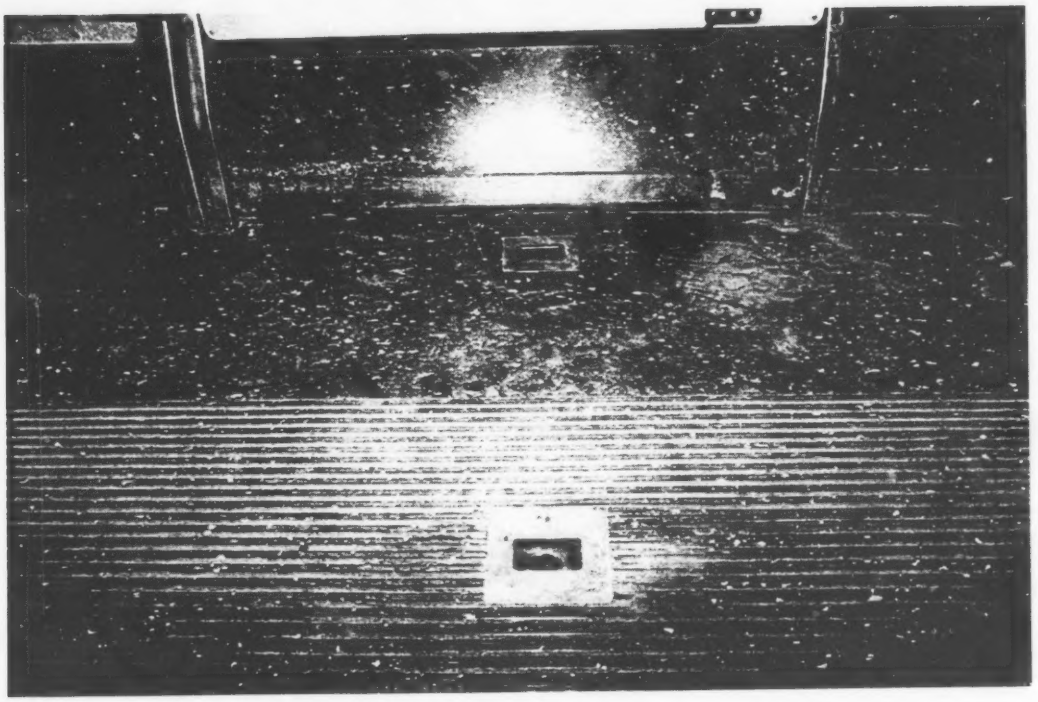

Fig. 13 Receptacle for front belt mounted in floor can easily get filled with dirt

APPENDIX C

Findings from German research on wheelchair-accessible buses

FINDINGS FROM GERMAN RESEARCH ON WHEELCHAIR-ACCESSIBLE BUSES

Two studies of relevance to CUTA's research were reported in the following document

"THE SECUREMENT OF WHEELCHAIR PASSENGERS IN URBAN TRANSIT BUSES AND IN MOTOR VEHICLES FOR DISABLED"
published for the Federal Ministry of Transportation by the Federal Highway Research Institute in Germany (BASt). Issue 88, 1992

German title:" Die Sicherung von Rollstuhlfahrern in Linienbussen und Behindertentransportwagen"
Herausgegeben im Auftrag des Bundesministers fuer Verkehr von der Bundesanstalt fuer Strassenwesen, Heft 88, 1992.

In this report the following two studies were particularly relevant:

" Wheelchairs in decelerated transport modes - limits for sliding and tipping".

"Passenger friendly and wheelchair accessible urban transit buses - acceleration measurements with wheelchairs in transit buses."

These two studies were translated and summarized by the author of the CUTA study in the following pages.

1.1 Overview of two studies

The Ministry of Transport (Germany) together with transit systems and the vehicle industry recognize the importance of making public transit more attractive for all people including those using a wheelchair.

With the introduction of low-floor buses, the opportunity to make transit buses accessible for wheelchair passengers increases significantly. This results in the question, whether the safe transport of wheelchair passengers requirers special measures in transit buses, and what is necessary to secure the wheelchair and to restrain the occupant.

To answer this question three studies were undertaken, two of which are relevant to transit buses. The first study by BASt carried out deceleration tests with a manual and an electric wheelchair placed unsecured on a moving test platform each loaded with a dummy. The objective was to establish the acceleration and deceleration forces which occur to bring a wheelchair passenger into an unsafe situation without using a securement system.

To complement the first study, tests were carried out by STUVA (The Research Commission for Underground Traffic Installations) to analyze which acceleration/deceleration forces are experienced by a manual and electric wheelchair in a transit bus under normal operating conditions in a city.

The conclusion of these two studies indicate that it is possible to transport wheelchair passengers in a transit bus **safely without a securement system,** provided that

- there is a "confined space" for a wheelchair passenger with a back-support panel
- the wheelchair passenger is facing rearwards with the wheelchair back in contact with the back support,
- the wheelchair brakes are firmly applied,
- the driver exercises reasonable driving habits,
- the speed does not exceed city speed limits

1.2 Detailed Summary of First Study

"Wheelchairs in decelerated transport modes - limits for sliding and tipping"
(Dipl.-Ing.Klaus-Peter Glaeser, BASt, 1990)

For the safe transportation of wheelchair passengers in public transportation, it is necessary that, under normal driving and braking conditions, a wheelchair which is secured by its handbrake only, neither slides nor tips beyond certain limits. By exceeding these limits, injuries could occur to the wheelchair passenger and or fellow passengers.

Objective

The objective of the tests carried out by BASt was to determine the minimum rate of deceleration by a vehicle which would result in the sliding or tipping of a wheelchair passenger in a manual and an electric wheelchair. No literature pertaining to this topic was found.

Set-up

66 braking test were carried out on a test platform at BASt. One manual and one electric (converted *) wheelchair were each loaded with a 75 kg dummy and their handbrakes applied. The brakes of the manual wheelchair act on the tire surface of the large wheels; the brakes for the electric wheelchair are drum brakes applied to the large front wheels.

(*) This electric converted wheelchair had large front powered wheels and small rear casters.

From a speed of 40 km/h (25 mph) the test platform was decelerated under various test conditions. They were as follows:

A. Dry surface - wheelchair facing front
B. Wet surface - wheelchair facing front
C. Wet surface - wheelchair facing sideways
D. Wet surface - wheelchair facing rearwards.

The surface of the test platform was a typical commercial anti slip floor material used in buses. Both wheelchairs were placed on the platform side by side, secured by slack belts, only to prevent the chairs from falling off. The belts allowed for a movement of
60 cm (23.6").

Results

During the tests the following conditions were observed:
1. Wheelchair remains in position or slides a maximum of 10 cm (4"),
2. Wheelchair slides more than 10 cm (4"), but less than 60 cm (23.6"),
3. Wheelchair slides a maximum of 60 cm (23.6"),
4. Wheelchair tips.

A. Dry surface - wheelchairs facing front
The results of 10 tests indicated that sliding starts at 2.1 m/s^2 (0.21 g) for a manual wheelchair and at 3.7 m/s^2 (0.37 g) for the electric wheelchair. A complete sliding occurs at 2.5 m/s^2 (0.25 g) for a manual, and at 3.8 m/s^2 (0.38 g) for an electric chair. None of the chairs tipped.

B. Wet surface - wheelchair facing front
The results of 8 tests indicated that sliding occurs at 1.8 m/s^2 (0.18 g) for the manual wheelchair and at 3.7 m/s^2 (0.37 g) for the electric wheelchair. At 3.7 m/s^2 (0.37 g) the manual wheelchair tipped completely to the front.

C. Wet surface - wheelchair facing sideways
7 tests were carried out and indicated that at 2.4 m/s^2 (0.24 g) the front casters of the manual wheelchair started to turn since they have no brakes. For the electric wheelchair turning of the rear wheels, which have no brakes, started at 3.0 m/s^2 (0.30 g). At 4,3 m/s^2 (0.43 g) both wheelchairs tipped over the front wheels.

D. Wet surface - wheelchair facing backwards
The results of 8 tests showed that the manual wheelchair's front casters started lifting and the chair tipped at 3.0 m/s^2, without sliding. The electric wheelchair started sliding at 2.4 m/s^2 (0.24 g) and slid the whole length at 2,9 m/s^2 (0.29 g). The tests also indicated that the backframe of both wheelchairs started to deform.

Conclusion

The following table shows the results of the deceleration values for the wheelchair types, their respective positions and surface conditions.

Table 1 Deceleration values for wheelchair types

SURFACE/POSITION	Manual wheelchair	Electric wheelchair
dry - forward	**2.1 m/s² (0.21 g)**	3.7 m/s² (0.37 g)
wet - forward	**1.8 m/s² (0.18 g)**	3.7 m/s² (0.37 g)
wet - sideways	**2.4 m/s² (0.24 g)**	3.0 m/s² (0.30 g)
wet - backward	2.9 m/s² (0.29 g)	**2.4 m/s² (0.24 g)**

The **bold** figures indicate the deceleration which should not be exceeded, otherwise sliding or tipping will occur.

Illustrations

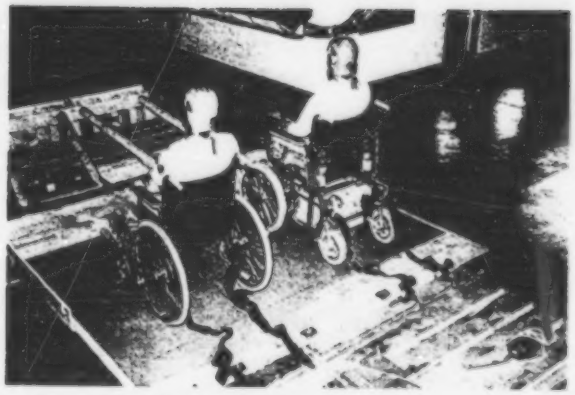

Fig. 1: Test platform with two wheelchairs

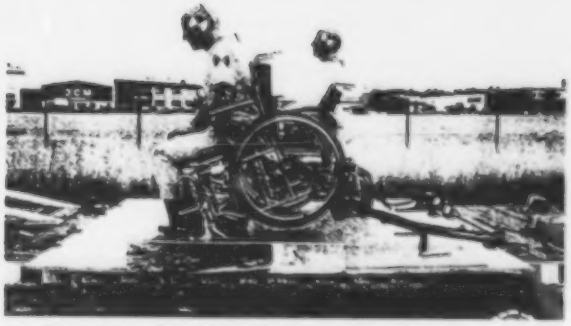

Fig. 2: Final position of wheelchairs facing forward on wet surface, after deceleration of 3.7 m/s² (0.37 g)

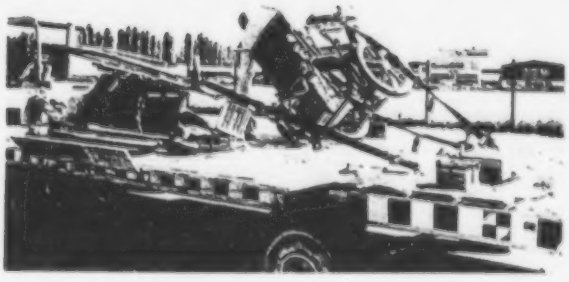

Fig. 3: Final position of wheelchairs facing sideways on surface, after deceleration of 4.3 m/s² (0.43 g)

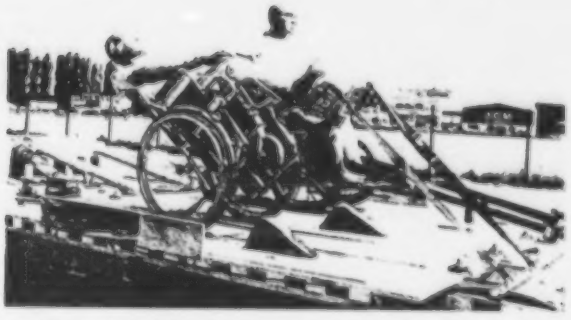

Fig. 4: Final position of wheelchairs facing rearwards, after deceleration of 3.0 m/s² (0.30 g)

1.3 Detailed Summary of Second Study

"Passenger-friendly and wheelchair-accessible urban transit buses - acceleration measurements with wheelchairs in transit buses"
(Dr.-Ing. Peter Kasten, STUVA, 1991)

Operators of urban transit buses, and often wheelchair passengers themselves, are of the opinion, that the "protected position" approach provides safe transportation. This "protected position" constitutes: a) a wheelchair passenger facing rearward with the wheelchair back against a panel installed in the bus, b) the sidewall of the bus, and c) the for and aft seat benches.

This approach is underlined by observations that even if securement systems are available in buses, wheelchair passengers seldom use them. The other fact is that there are no accident reports of transit buses where wheelchair passengers were injured.

Objective
The objective of this test program was to answer the question " Which forces and accelerations/decelerations apply to wheelchair passengers in an urban transit bus?"

Set-up
One small type bus (BTW) and two regular low-floor transit buses were tested for a total of about 300 km (190 miles) in the cities of Cologne, Wuppertal, and on rural and regional roads with a topography including typical hills, curves, and descents. The buses, due to their modular design have two places for wheelchairs always in the same location, at the midsection opposite the entrance/exit door. The bus floor was of non-skid commercial material typically used in these buses. The wheelchairs were the same type as used in the BASt study, one manual wheelchair and one electric converted wheelchair. A dummy of 75 kg (165 lbs) was placed in the respective wheelchair.

Results
During the trips 3 axial acceleration measurements were taken at the bus floor level and at the wheelchair's seat height. The use of a dummy simulated an extreme condition of a wheelchair passenger, one who can not intentionally shift the bodyweight or hold onto a seat, stanchion etc. The majority of the observed changes in the wheelchair position during trips could be eliminated if the wheelchair passenger could hold onto something or if a companion be present.

The ratings of deceleration measured at wheelchair seat height are substantially smaller than the ones measured at the bus floor level, due to the spring action of the air filled wheelchair tires.

Under normal operating conditions accelerations of 2.4 m/s^2 (0.24 g) in vertical, horizontal and transversal directions were occasionally exceeded by up to 5%*. When curves were driven more forcefully, the rating was exceeded by up to 11%*. When the wheelchair was placed facing sideways in some cases the front

casters of the manual wheelchair started turning or the chair started sliding (up to 5 cm, 2"). In most cases the wheelchairs remained in place.

Note: (*) The variations of 5% and 11% were due to measuring equipment and occurred only for a time of 1/200 second. This had no impact on the movement of the wheelchair.

When facing backwards and supported against the back panel, higher acceleration values - from abrupt braking to emergency braking- can be absorbed. It is important that the back panel be wide enough to support the full area of the wheelchair back. It is also important that both rear wheels can touch the seat bench/support.

In other positions (at rear location in the bus, without support of back panel) such as facing sideways, wheelchairs can slide severely or even tip under severe braking conditions.

It was generally observed that the electric wheelchair was less affected by acceleration and deceleration forces due to its total weight construction and lower point of gravity than the manual wheelchair.

Conclusion

The results of the tests by BASt and STUVA correspond rather well with each other.

One factor which would improve the stabilization of the wheelchair significantly would be the application of brakes on all four wheels. This would prevent the front casters of the manual wheelchair from moving into different positions, and stabilizing the steering wheels of the electric wheelchair.

Important in any case is that the brakes on wheelchairs are in good condition with equal braking power on each wheel. Wheelchairs using brakes which apply to the tire surface must insure proper air pressure.

In summary it can be said that under normal bus operations there is no danger or likelihood that a wheelchair will slide or tip. In the rearward facing position with the use of the backpanel, even severe and emergency acceleration and deceleration forces can be absorbed. Under the present safety regulations this allows for only one wheelchair to be transported per bus.

Another aspect, which is of equal importance, is that of the operators driving habits which can affect acceleration and deceleration forces considerably. Severe accelerating, abrupt braking and aggressive driving should be avoided in the interest of all passengers, especially for those who are standing.

Illustrations

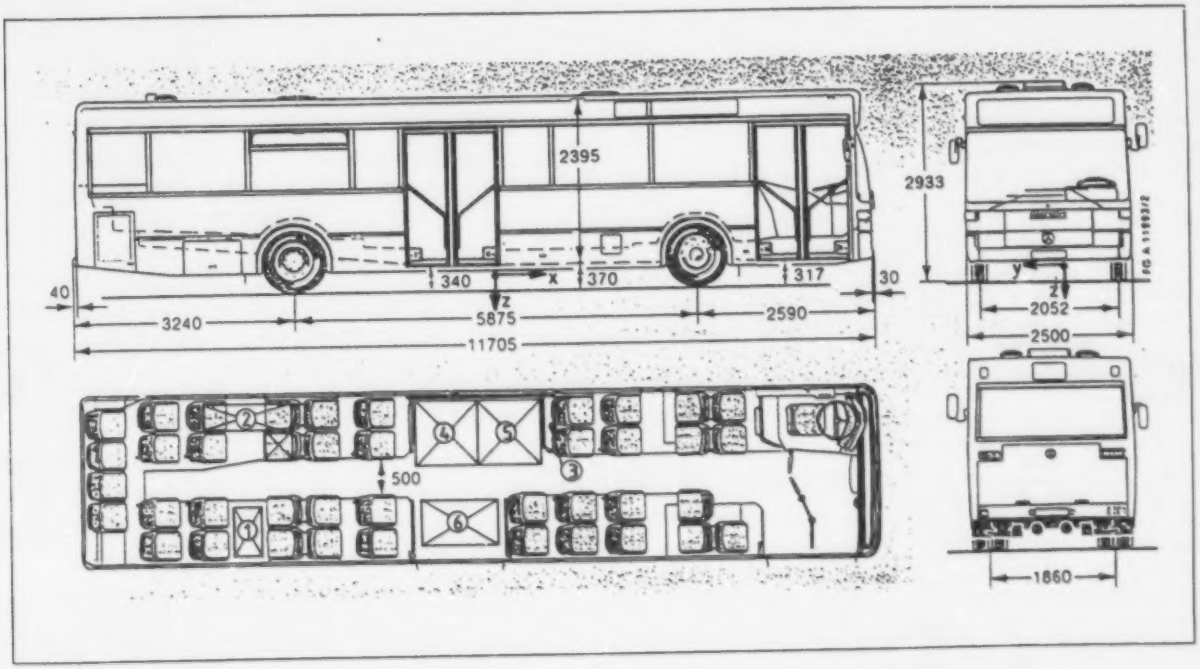

Fig. 5 Views of the low-floor bus used in tests (Type DB 0405N)

1: Static transformer
2: Measuring equipment
3: Three-axis measuring equipment
4: Place for wheelchair - rear
5: Place for wheelchair - front
6: Storage for unused wheelchair

APPENDIX D

CUTA Forum article "Low floor takes to the streets of London"

the Traveller's notebook

Public transport -- English-style -- Part II

This month we continue our look at transit in England with a more detailed examination of bus operations, including a review of London's new low floor buses.

Low floor takes to the streets of London

On January 29, 1994, low floor buses took to the streets of London on the first of five regular routes to be converted this year. This article takes a look at operations on the first route and at the initial group of low floor buses.

The project

Working with the British Department of Transport, London Transport (LT) is conducting a trial of low floor buses and will assess the impact of such vehicles in the United Kingdom. Working through LT's Unit for Disabled Passengers, three routes were identified for the initial test and specifications were drawn up for the purchase of new, low floor buses.

Tenders were sought in the summer of 1992 for buses, and bids were received from Belgian, Dutch and British suppliers. Subsequently, An order for 38 low floor buses was placed. Later, two additional routes were added to the program and a further 30 buses ordered.

London's project is heavily-based on the German experience, where over 3,000 low floor buses are currently in operation. German research in the 1970s indicated that service could be made more efficient through the use of step-free loading and unloading. Needless to say, the benefits to a wide range of passengers, including the frail elderly, passengers with children, and those with baby strollers and parcel buggies, were also noted, not to mention wheelchair access.

The first route

First to be converted to low floor bus operation is route 120, operated by London United Busways Limited, one of the London Buses units of London Transport. The line links the Hounslow Bus Station (east of Heathrow Airport) with the Northolt area.

"... service could be made more efficient through the use of step-free loading and unloading."

Service is provided seven days a week, approximately every 15 minutes during the Monday to Friday daytime hours. A 30 minute service is provided evenings and weekends. As many as ten buses are required for the route with seven required for base service. A one way trip is scheduled for approximately 45 minutes. The route passes through a mixture of high density commercial and medium density, suburban residential areas, with good on and off traffic along the route. Most roads traversed are two lane with curbs and sidewalks.

The vehicles

As is the case with most buses sold in the U.K., separate chassis and body orders were placed for the low floor buses. For the first group of 38 vehicles, "Lance" single deck chassis were specified from Dennis Specialist Vehicles Limited. Bodywork was ordered from Wrights of Ballymena in Northern Ireland, using a bolted aluminum "Alusuisse" construction technique. The second order of 30 units will use chassis supplied by Scania (UK) Limited with similar Wrights bodywork.

The bus carries basic dimensions of 11.1 metres (36.8 feet) long, 2.5 metres (8.2 feet wide) and 3.0 metres (9.9 feet) high. The bus is powered by a Cummins C8.3 litre, six cylinder, diesel engine delivering 211 horsepower, coupled to a ZF 4HP 500 automatic transmission. The maximum gross design weight is 17,500 kilograms, with the unloaded weight being 9,440 kilograms.

One of the first of 38 new low floor buses operated by London Transport is seen in the Hounslow Bell area on route 120 early in February 1994.

Externally, the buses are painted in the standard London Buses red, and are clearly identified as low floor. A large, three piece windshield includes separate, large destination and route blinds with yellow on black lettering. The front entrance includes a "slide-glide" door with large double windows. The centre doors are of a plug-type design, again with two piece windows. Large side and rear windows complete the basic body design.

An extendible ramp is built into the bus at the centre door in order to bridge the gap between the bus and the curb. The normal height of the bus floor is 320 mm (12½") above the road, while the kneeling feature reduces this to 240 mm (9½").

On the inside the buses are similar in many respects to the low floor design from New Flyer Industries, which itself is based on European concepts. The London United buses have 31 forward and rearward facing seats with one wheelchair position. In addition, there are three additional flip down seats in the wheelchair area that can be used if no wheelchair rider is present. Areas over the front wheels are used as parcel racks. Thirty-three standees are allowed.

The floor is level from the front door until past the centre door. Two relatively shallow steps are employed to raise the floor over the rear axle, the first step having a row of seats level with the step. The two step edges are marked by yellow and black contrast markings and red lamps in the floor. Seats are located on the upper floor level, with one additional step up to the seats over the rear engine compartment.

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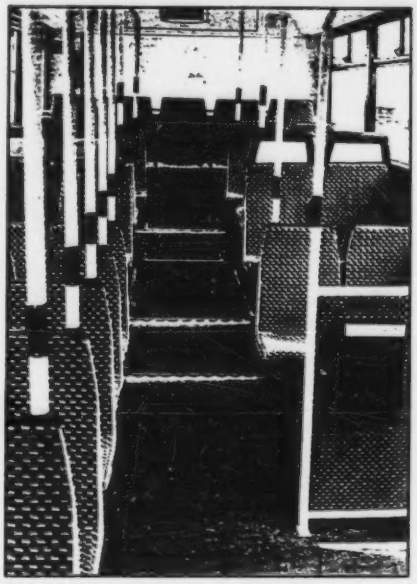
Low floor takes to the streets of London

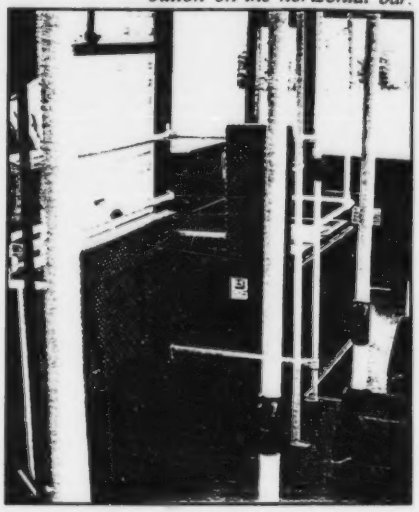
... Continued from page 12

All passenger stanchions are textured and bright yellow, with most including palm-activated signal bell pushes. The wheelchair position is located on the door side. Wheelchair riders are instructed to board and face rearward, positioning themselves with a padded rest behind them, a padded area on the window side (with the flip down seats), and a vertical stanchion on the aisle side. In the German style, no other securement devices were felt to be required. A signal button on a horizontal bar in this area is used to signal the driver that the wheelchair ramp is required at the next stop (see below).



[↑] *Looking back from opposite the wheelchair position, this view clearly shows the intermediate steps and seating arrangement. A total of four seats face backwards. Note the contrast markings and red lamps along the two step edges.*

[↓] *The wheelchair area is located between the front wheel and the centre door. Wheelchairs face rearward with the rider's back against the vertical cushion. A padded stanchion and three flip down seats protect the rider on one side, while a vertical stanchion is located to the left of the passenger. Note the ramp request button on the horizontal bar.*



The London low floor operation

Before discussing the specifics of low floor bus operation in London, it is important to note that all drivers for London Bus units are instructed to use the parking brake whenever stopped, even if just for a traffic signal or at a passenger stop. For this reason the parking brake handle is located to the right of the driver in a very accessible position.

On the low floor bus, drivers have been instructed to use the brake and kneel the front of the bus at every stop. The kneeling process takes about the same length of time as opening the doors.

Once lowered, the doors are opened. Should the ramp be requested by a passenger wishing to leave, the entire door side of the bus would have been lowered upon stopping and the ramp extended before the doors are opened. (In its wisdom, British Transport authorities have decided that the ramp cannot be operated with the doors open.)

"... all drivers for London Bus units are instructed to use the parking brake whenever stopped ..."

External buttons allow intending passengers to request the ramp, but given the current regulations, this means the doors must be closed, the front of the bus raised, the side of the bus lowered and the ramp extended before the doors can be re-opened to allow the wheelchair rider to enter.

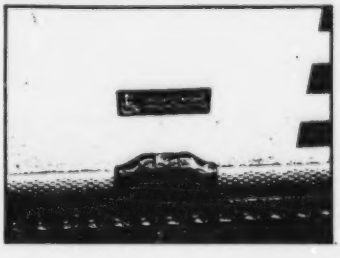
[↑] *The centre door area of the bus showing the exterior passenger ramp request buttons.*

Other vehicle features

As with all London Bus vehicles, drivers are "contained" in the operator's compartment by a solid half door and security screen – remember, drivers still sell tickets and make change. In order to supervise the centre door area, a small video camera is mounted near the ceiling, flush to the inside wall. A video monitor is provided to the upper right of the driver to allow the area to be viewed.

Also in common with other buses in London, the front door is opened by means of a foot switch located to the left side of the driver. The switch will not allow the door to be opened while the vehicle is in motion. The centre door and kneeling of the bus are controlled by

See page 14 ...



[←] *The ramp/stop request button for wheelchair riders, located on the lower horizontal bar to the right of the passenger. The bar is textured and bright yellow in colour (as are all stanchions and bars).*

All photos by David Onodera.

Low floor takes to the streets of London

... Continued from page 13

push buttons to the right of the driver.

Route and destination sign curtains are controlled from a single console near the driver, and buses are radio-equipped.

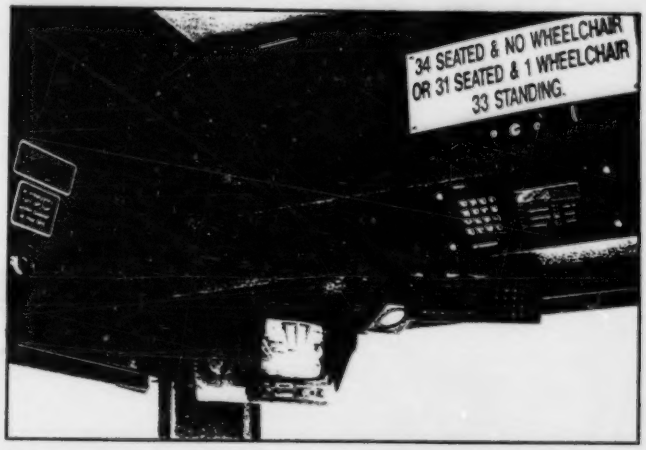
The early results

At the time this article was being researched in early February, it was too early to come to any conclusions about the operation of low floor buses in London. However, it is reasonable to predict that people in London will find the buses more attractive and easier to ride on than their conventional counterparts (especially double deck buses!).

The initial buses were designed and built to London Transport specifications. A prototype bus was thoroughly reviewed by both staff and user groups, including members of the disabled community -- both ambulatory and non-ambulatory. The Unit for Disabled Passengers at London Transport played a significant role in ensuring that the buses met the requirements of as broad a spectrum of the market as possible.

The route 120 test is being heavily marketed by London United through special timetables and brochures. Indeed, the buses themselves are very difficult to miss, with their low floor markings.

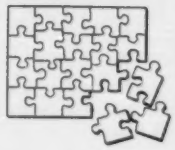
Perhaps the most interesting and most controversial aspect of the test is how passengers in wheelchairs will fare in the securement-free environment, but if the early reaction is any indication of things to come, today's low floor buses are providing a look into the future for transit riders in London, and in many other areas of the country as well. ◂◂



[↑] *A small video monitor located to the upper right of the driver allows for monitoring of the centre door area. The speaker and console on the right are part of the two-way radio system, and the console above the radio controls destination and route signs.*

[↓] *The ramp extends out from under the door, only with the doors closed. When fully extended, the doors can be opened. The ramp is equipped with a sensitive edge that will cause it to stop if its progress is impeded.*

Transit Planning...



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